GRAZING EFFECTS ON HERBAGE COMPOSITION AND NUTRIENT DISTRIBUTION ON A FLORIDA RANGE FLATWOODS

By

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"There is something fascinating about science: One gets such wholesale conjecture out of such a trifling investment of fact."

Mark Twain

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The effects of short duration-high intensity grazing systems on a flatwoods site at the Beef Research Unit, Gainesville, Florida, were investigated from July 1976 to September 1977. Length of rest was the variable, with four replications and four treatments of two, four, six and twelve (control) months rest. Grazing was regulated to remove 50% of available forage, determined prior to cattle entry. Herbage samples were collected prior to and after grazing and forage production determined. *In vitro* digestibilities, and chemical determinations for phosphorus, calcium, and potassium were conducted on herbage samples for each collection period. Soils, groundwater, precipitation, insects, fecal and litter decomposition were monitored to obtain a total ecological picture of the effects of one year's grazing on flatwoods.

Forage production trends indicate that three to four months rest at 50% utilization levels result in the highest production. Cattle production data indicated that this level was too high and a 30 to 40% utilization of flatwoods ranges is suggested. Clipped forage samples were below minimal requirements for dry cows in phosphorus and energy. High Ca:P ratios exist in the native forages, averaging approximately 5:1 over the year. Cattle

were found to be actively selecting the outer one-half bud of Serenoa repens in an apparent attempt to rectify this Ca:P imbalance. This portion of the bud has the lowest Ca:P ratio of any part of the plant. This same imbalance may well have implications for white-tailed deer management in the state.

Soils at the site are highly variable in chemical content, especially phosphorus. Phosphorus content of the top 30 cm of soils averaged approximately 12 ppm with individual pasture values of less than 0.5 ppm. This high variability of phosphorus, also noted within plant species, may be indicative of low nutrient sites and is suggested as a method for determining the limiting element for production of such sites. Lateral flow of nutrient containing water in the micro-relief of the soil is proposed as one mechanism responsible for the high variations noted in the soil profile. There appeared to be a positive relationship between phosphorus content of the soil and foliar content in plants. Phosphorus input from rainfall was less than one kilogram per hectare per year; however, on phosphorus deficient sites this represents a significant input.

Mineral supplementation of cattle considerably increased the phosphorus levels in the soil. The duration of the experiment was too short to note any meaningful changes in foliar chemical content or species composition. However, foliar content of phosphorus in needles of longleaf pine (Pinus palustris) are higher ($P < 0.05$) in the two-month rest pastures than in controls during the winter. The phosphorus cycle was simulated on the analog computer and understory plants reacted favorably to additions of phosphorus via cattle supplement.

Results of the insect study are tentative but indicate that biomass of the insect population may exceed that of cattle grazing the area.

The Florida flatwoods exhibit characteristics similar to the tropical areas of the world. Of 21 grasses at the site, 20 were of the C_4 pathway. This high preponderance of C_4 plants is indicative of tropical environments rather than temperate ones. The implications of this are that grazing systems developed in the Western or Northern areas of the United States are not necessarily appropriate for Florida. Range management in Florida should address itself to tropical or subtropical areas of the world and research those systems that show promise of being adapted to local conditions.

CHAPTER 1

INTRODUCTION

Florida has had cattle longer than any other state in the Union but, from the standpoint of future potential and development, it is one of the youngest cattle states (Cunha, 1976). The Southeastern states, Florida in particular, have the largest potential for increased cattle numbers through the increased use of native range, improved varieties of forage, and management techniques suited to the local conditions than any other group of states in the nation (Little, 1977; Conner, 1977; USDA, 1975).

Florida's native vegetation has a production potential exceeding most areas of the United States (White and Carter, 1977). "However, at present much of the woodland in Florida does not fit the image of a managed forest nor does much of the range fit the image of good grazing" (Commissioner D. Conner, 1977). About 6 to 8% of the native forage resource is being managed to its full potential (Yarlett, 1977).

Cattle numbers in Florida have been increasing at the rate of 5% per year from 1967 to 1976. This compares to a national rate of increase for the same time span of 1.8% (Florida Department of Agriculture Staff, 1976). It is estimated that by the year 1985 Florida will have increased its beef herd 36% over 1974 and will be producing 82% of the non-fed and 28% of the fed beef that the state consumes (Cunha, 1976).

Florida flatwoods make up about half of the land area in Florida (Pritchett and Smith, 1974). The major forage component of this range consists of wiregrass and saw palmetto. The fact that large areas are covered by this

type of vegetation is not a tribute to its desirability by ranch managers, but rather is the result of years of misuse. This situation has resulted from the attendant management practice of burning and immediate grazing that was developed as a necessary feature in order to obtain economical gains from range cattle enterprises. This is the periodic burning of the wiregrass range in order to remove the old herbage and stimulate new growth which is palatable to cattle. For a wiregrass range, Duvall and Hilmon (1965) showed that a three year burn rotation produced substantially more useable nutrients than an unburned range. Even so, a pine/wiregrass range is nutrient poor and generally does not meet the yearly requirements of dry cows without supplementation (Moore, J., 1977; Lewis et al., 1975). The end result of this type of use has been a decrease in the more desirable forage species and an increase in the poorer quality plants.

Beef production on native range amounts to about 22 Kg/ha, compared to 336 Kg/ha on improved pastures with good management (Moore, 1977). Knowledge of forage quality of various range plants in Florida is due primarily from the result of practical experience. Experienced ranchers know which plants are preferred by the grazing animal and which plants result in the best performance; maidencane (Panicum hemitomon) is a case in point (White, 1977[1]; Camp, 1932).

Forage quantity has little meaning unless some index of quality is known. When an area is evaluated solely on the basis of available dry matter, as it often is, capacity is generally overstated (Blair et al., 1977).

Except for wiregrass (Killinger, 1948; Hilmon et al., 1962), nutrient content and digestibilities of native range species in Florida are virtually non existant (Ammerman, 1977). Young (1977) has looked at eight species over a four month period from a flatwoods range at the Beef Research Unit (BRU). Lewis et al. (1975) have reported on species that are common in Florida but

1. White, L. D. 1977. Assoc. Range Prof., Univ. Fla., Personal communication.

were grown in Georgia. Several investigators have reported chemical values for native range, but not by species (Halls, et al., 1956; Koger et al., 1961).

Forage quality of a species, in terms of nutrient content and digestibilities, have little meaning unless some measure of intake by the grazing animal is also known (Abrams, et al., 1978). A start in determining forage intake has been made by Gumma (1977) for range species in a flatwoods site, by determinations of bite count and microscopic point analysis of an esophageal-fistulated cow.

The intensity and frequency of grazing will dictate the kinds of grasses that will exist on a native pasture (Yarlett, 1977). Animals will graze the most palatable species more frequently. This continued cropping causes the plant to lose vigor and results in replacement by a less desirable species. With the knowledge of the growth patterns of the important range forage species, management systems can be developed that will account for the critical periods of a plant's growth. Knowing when to close and open the gates is the key to any grazing management system.

In general, transplanting of systems of management that are successful in the West, such as various deferred grazing and deferred rotation, are not successful in the South (Duvall and Hilmon, 1965; Biswell and Foster, 1947). However, a promising alternative to the practices used in Florida in the past appears to be the high intensity-short duration grazing system. This technique places large numbers of animals into small pastures for short periods of time, followed by long periods of rest (Norris et al., 1975). Such a system was studied by Felts (1976) at the BRU. She concluded, after a one year study, that a four to six month rest, following 50% removal of available forage, appeared to give the most promising results. This system is also being used in South Florida by commercial cattlemen.

There exists a need for an integrated study utilizing an ecosystem approach to define the various components that are interacting in the existing system. A need exists for data on the nutrient quality and digestibilities of the range species in a flatwoods site both for wildlife and livestock managers. The short duration grazing system should be researched further to determine the effectiveness under sub tropical conditions.

Based on the hypothesis that the short duration grazing system is valid under Florida conditions, the objectives of this study are to:

1. Determine nutrient content and digestibilities of native range plants.
2. Further analyze the short duration-high intensity grazing system.
3. Determine interactive effects of a grazed flatwoods ecosystem.
4. Make specific recommendations for future research and management techniques for best utilization of a flatwoods range ecosystem for livestock production.

CHAPTER 2

LITERATURE REVIEW

The first cattle to arrive in the United States landed on the Gulf Shore in 1521, when Ponce de Leon brought cattle to supply his projected colony (Bryan and Sharrock, 1941). Additional stock was brought by DeSoto in the 1530's (Yarlett, 1961). "Some of those animals evidently outran the butcher and escaped into the woods, for later settlers found Indian tribes in possession of half-wild cattle, descendants of which have been kept on the run ever since, frequently consuming more miles than sustenance in the search for forage" (Bryan and Sharrock, 1941, p.4).

Cattle were herded in the vicinity of St. Augustine as early as 1712 by cattlemen supplying beef to the Spanish garrison (Yarlett, 1961). Great herds were owned by Miccosukee Indians, with Chief Micanopy running a large herd on Payne's Prairie in the 1770's (Buchholz, 1929; Yarlett, 1961). By the late 1820's many settlers, both Spanish and English, had taken up land in North Florida for the purpose of raising cattle. This settlement was further hastened by the building of the Bellamy Road from St. Augustine to Tallahassee in 1826 (Camp, 1932). The major shipping points at this time were Tampa and Punta Rassa, with Cuba the main market. Over 30,000 head of cattle were shipped to Cuba from Punta Rassa in 1840 (Camp, 1932).

Commercial stock raising received further impetus during the Civil War when stockmen supplied beef to the Confederacy. "It was through this period that such noted range kings as Jake Summerlin, H. T. Lykes, and Ziba King popped their 18-foot whips over big herds that waxed temporarily fat during the spring and early summer" (Bryan and Sharrock, 1941, p.11).

Numerous herds were brought into Florida from Georgia and the Carolinas between 1830 and 1850; however, the first improved breed was a Devon bull introduced in 1861. The first Brahman cattle were introduced in 1880, when four bulls were brought to Cedar Key (Camp, 1932). Dodd (1954) disputes this, claiming that four crossbred Brahman bulls were introduced by 1859 in South Florida. By 1900, most of the English breeds had been established in Florida.

The introduced cattle had a host of problems to overcome, aside from the poor quality of the range during much of the year. Cattle tick fever took a high toll. Out of a carload of Hereford bulls shipped from Texas, only three were alive nine months later (Camp, 1932). The eradication program for tick fever was begun in 1920 and completed in 1950 (Cunha, 1976). Salt-sick, a nutritional anemia caused by a deficiency of iron, copper, cobalt, or some combination of these elements, was first suspected by Maxwell (1888). Stockbridge et al. (1902) first demonstrated an iron deficiency among cattle on native range. Specific recommendations were not made for correction of these conditions until 1931 (Becker et al., 1931). Local cattlemen did recognize these problems and got around them somewhat by rotating cattle from pasture to pasture or, on unfenced ranges, establishing a hospital farm on a wholesome pasture (Becker et al., 1965).

Other common problems noted by early ranches were paces, limehided, marsh sickness, and falling disease. Lack of copper was the major contributor, but this was not ascertained until recently (Becker et al., 1965). Screwworms were not brought under control until the late 1950's. Mosquitoes, horseflies, internal parasites, and a host of other pests still plague cattle in spite of various programs of spraying, dipping, or dusting.

Florida cattlemen have not been particularly adept at accepting new concepts or ideas. Salting was a well accepted practice in the early 1900's

on Western ranges (Doc Smith, 1948, old time Wyoming cattle rancher, personal communication), however as late as 1932 only 15% of the ranchers in Alachua County salted their cattle (Camp, 1932). Rummell (1956) has also commented on the low level of management in South Florida.

One area where ranchers did raise a clamor for new concepts was in the use of improved pastures, beginning about 1920. In 1924 a series of experiments were conducted with introduced grasses by the Agricultural Extension of the University of Florida, Seaboard Airline Railway Co., and the Florida East Coast Railway Co. (Bryan and Sharrock, 1941). A mixture of carpetgrass (Axonopus compressus), Dallisgrass (Paspalum dilatatum), Bahiagrass (Palpalum notatum), and Japanese clover (Lespedeza spp.) were used on several locations throughout the state; annual carrying capacities were reported from one to two cows per acre.

Numerous experiments followed; Ritchey and Henley (1936) looked at different grasses alone and in mixture and Leukel and Stokes (1942) worked at establishing carpetgrass under range conditions. Pangolagrass (Digitaria decumbens) was first introduced to researchers at the University of Florida in 1936 and later released to farmers and ranchers in 1943 (Hodges et al., 1975). Breeding programs and testing procedures were developed to test promising new varieties and cultivars of different forages and are continuing to this day (Moore and Ruelke, 1978).

While results of these early tests of improved pastures were made known, Florida, like the rest of the nation was in the midst of the "great depression." It wasn't until 1936 when financial aid was made available through the U. S. Department of Agricultural Adjustment Administration that large scale planting by cattlemen began (Bryan and Sharrock, 1941). The only hitch was that in order to obtain this aid the land must be fenced. At this time Florida was an open range state in most counties. This allowed the larger, more

affluent, cattlemen (being in better financial condition) to take advantage of the new improved pasture grasses, which they did. One rancher in Collier and Hendry Counties bought and fenced 38,000 acres each year; Carey Carlton, with herds in DeSota, Hendry, Glades, and Highlands Counties converted 7000 acres between 1939 and 1940 (Bryan and Sharrock, 1941).

The passage of the "No Fence Law" by the Florida Legislature in 1949 resulted in better quality cattle and higher production of forage (Killinger, 1960). Beef cattle were confined by fences to more restricted areas which made for a forced type of rotational grazing. Range management had arrived.

In a general sense of the word, range management began with the advent of man into the Florida environment some 10,000 years ago (Griffin, 1974). Early man used fire as an aid in hunting, a method of clearing ground, and later to provide forage for his cattle (White, 1975a). Fire was the first management tool to be used by ranchers in this state and remained about the only one until the mid-1950's (Rummell, 1956). Cattlemen used fire to control the growth of brush and weeds, stimulate new growth, and to remove dead grass. Controlled rotational burning was practiced every two to three years on the flatwoods. Ranchers generally felt that there was nothing to be gained by burning the prairie, hammock, and blackjack ranges where the undergrowth was thin. The indescriminate use of fire was frowned on by most of the early ranchers as most, if not all, had experienced some economic loss from wild or escaped fires (Camp, 1932).

Fire is a controversial subject with many arguments on both sides. Numerous studies were made to determine the effects of fire on the Coastal Plains of Florida and Georgia. Lemon (1946) studied the effect of fire on the Coastal Plain of Georgia; Killinger (1948) looked at the effect of fire on wiregrass ranges in Florida; Rummell (1956) reported stocking rates on burned flatwoods ranges in Florida; and Hughes (1974) noted the effects of

fire on wiregrass ranges in South Florida. In general, all agreed that burning increased the nutrient content of the native range, but that this effect was temporary. Hilmon et al. (1962), working on a wiregrass range in South Florida, reported that the nutrient content, protein, and chemical composition was almost doubled in a few months after a fire, but had returned to near original levels by the end of a year.

Early observation of repeated burned ranges, noted that certain kinds of plants seem to predominate. They were broomsedge (Andropogon virginicus) and wiregrass (Camp, 1932). Later studies by Hilmon (1968) found that fire increases the range of saw palmetto and Parrott (1967) reported the same effect for wiregrass. This practice of burning the range continued almost unabated until the 1940's. The end result was a general deterioration of the range, the more palatable and nutritious forage being all but eliminated. The shift to improved pastures brought a much needed respite to the range areas. The Florida range lands of today are in much better condition than they were 50 years ago (White, 1975b).

Range management in Florida can be dated from the publication of "A Study of Range Cattle Management in Alachua County, Florida," by Paul Camp in 1932. This was essentially a survey of existing practices in the ranching community around Gainesville in the early 1930's. Little more was written on the subject, probably due to the interest in improved pastures and World War II, until 1942. The Coastal Plain Experiment Station in Tifton, Georgia, had been conducting research on cattle grazing on the Coastal Plain and a survey of forest grazing and beef cattle production was published by Biswell et al. (1942). Wells (1942) reported on the ecological problems in the Coastal Plains and presented a coherent picture of the ecology of the Coastal Plains. The year 1945 saw Nieland formalize his multiple use concept (Nieland, 1945), a plan which was apparently some 25 years ahead of

its time, and the U. S. Forest Service admitted that grazing was alright for Southern pine ranges (U. S. Forest Service Staff, 1945). The 1948 yearbook of agriculture also devoted a chapter condoning the grazing on Southern ranges (Cassady and Shepherd, 1948). This position was moderated considerably, primarily as a result of grazing studies in the hardwood regions of the North indicating damage to the forest (Morrow, 1955; Williams, 1951). Also as a result of a study reporting sheep damage to longleaf seedlings (Mann, 1947) and a study in the Coastal Plain by Cassady et al. (1955) which noted cattle damage to pine seedlings. The bias against grazing cattle in Southern forests persists to this day, although the evidence indicating damage under proper management is slight (Lewis, 1977).

Rotational grazing on a native Coastal Plains range was studied by Biswell and Foster (1947) in North Carolina. Three different systems were investigated; continuous grazing, rotation at mid-season and a 28-day rotation. They concluded that all three systems gave essentially the same results.

Fertilization of wiregrass ranges in conjunction with burning was investigated by Killinger (1948) at Gainesville, Florida. At 211 days after treatment the unburned, unfertilized plots were higher in dry matter but lower in the elements tested for than the burned plots. The plots that received 2-14-10 at the rate of 672 Kg/ha (600 lb/acre) plus micro-elements had the highest levels of nutrients in the foliar analysis, with P being 0.57%.

A survey was conducted in West Florida by Brasington (1949)[2] of the use of the forested range lands. Out of 132,000 head of cattle 41% depended entirely upon the native range for sustenance (without supplementation of any kind), 32% had below standard winter supplement and the balance utilized the woods on a part time basis.

Brasington, J. J. 1949. Unpublished data, So. For. Exp. Sta., New Orleans, La.

With the passage of the No Fence Law and depressed cattle prices in the mid-1950's, a renewed interest in the range was generated. Intensive range research in Florida did not begin until 1953 (Rummell, 1960). An analysis of range problems in South Florida was published in 1956 (Rummell, 1956). This report showed that in this area, with more than 10 million acres of native range and a population of over a million head of beef cattle, a very low level of native range and cattle management was practiced. In 1955, the Caloosa Experimental Range became the center for U. S. Department of Agriculture range research in South Florida (Rummell, 1960).

With the discovery that litter, rather than shade, was the dominant factor in limiting understory production, particularly with respect to planted clovers (Halls, 1955), efforts were begun to devise methods for measuring vegetation in the pine regions of the Coastal Plains. This work culminated in the publication of a technique and methods manual, the results of a symposium held in Tifton, Georgia, in 1958 (Southern and Southeastern Forest Experiment Stations Symposia, 1959). For the first time a comprehensive description of methods and techniques especially adapted to measuring the understory of the Southern ranges was available. Later, other technical guides have also been available to Soil Conservation Service Staff and field workers (SCS Staff, 1975, 1976).

Gatherum (1955) showed a preliminary cost return combination for maximizing profits on management of forest lands for timber and cattle. Yarlett and Moore (1963) investigated the utilization of Gulf Coast salt marshes for cattle production and noted that the dominant invader, Black needlerush (Juncus roemerianus) can be effectively controlled. Halls et al. (1964) published a guide for use of the longleaf-slash pine forest for forage and cattle management. Application of rock phosphate applied to cut over and

chopped native ranges was found to double yields when applied at the rate of one ton per acre (Lewis, 1963; Hilmon et al., 1962).

Determinations of native grasses that furnish forage indicated that of 350 species of native grasses found in Florida, 147 are important in furnishing forage to livestock (Yarlett, 1963). Consciousness that all grass is not wiregrass and should not be managed as such was making itself apparent to ranchers (Yarlett, 1965a).

About this same period of time heavy machinery began to be used for range improvement work. Bulldozers or road patrols, pulling drum choppers or webbers (a V blade, designed to cut off roots just below ground level) were first used to clear land for improved pastures (Reuss, 1958) but were later used on rangelands with promising results. Lewis (1972) noted that webbing was less effective than cross-chopping especially on moist sites for the control of shrub species such as saw palmetto.

Estimates of forage quality of native species have depended primarily on studies conducted in other states. Lewis et al. (1975) reported values for in vitro digestibility (IVOMD) for several groupings of understory plants in Georgia. Earlier, Halls et al. (1956, 1957) had reported values for wiregrass and other species on native ranges in Georgia. Hilmon and Douglas (1967) reported that the effects of fertilization on a forested range watershed in South Florida caused changes in the plant composition and that the rate and/or direction of plant succession may be altered. Significant gains in livestock and wildlife foods were also reported in this study. Yarlett (1965b) published a list of important native forage grasses in Florida. Lists of plants native to Florida and their potential were summarized as to ecosystem type by White (1973). An economic study by Hughes (1975) showed returns of $2.50, $2.00, and $1.25 per acre for high, medium, and low rates of stocking in a study at the Caloosa Experimental Range, South Florida.

The short duration grazing system was investigated by Felts (1976). The results were inconclusive but trends indicated that a rest period of between four to six months was best suited after removal of 50% of the available forage. Gumma (1977) obtained the first data on cattle diet selection of native species on a flatwoods range; some plants that were not suspected of being utilized (e.g. grassy leaf golden aster) were found to supply a sizeable portion of the diet. Young (1977) also worked on a short-duration grazing system as affecting diet quality and reported on the IVOMD and chemical content of six range species during four months of growth. Anderson and Hipp (1974), on an economic evaluation of pasture and range operations in Florida, found the highest returns to land were from irrigated pastures, but the highest returns per animal were from all range operations.

With the inactment of the Forest Rangeland Renewable Resource Act of 1974 by the U. S. Congress, national direction was shifted to the concept of multiple use. The assessment made of the nations renewable resources (USDA Staff, 1975) focused on areas of prime interest of the nation as a whole with the Southeast showing the greatest potential. Nieland's (1945) plan became tenable for Florida. Investigators began to look seriously at multiple use systems (White, 1977). This interest resulted in range (for the first time) getting equal billing with forest and wildlife at the 1977 symposium "Mutual Opportunities for Forest, Range, and Wildlife Management" held at Gainesville, Florida.

Range management in Florida is at the threshold of making significant contributions to the economic picture of the state. The high cost of fertilizer, coupled with the increasing cost of energy, will place the native range in a more favorable light to livestock producers.

CHAPTER 3

SITE AND METHODS

Physical Site Description

The study was conducted at the Beef Research Unit (BRU), approximately 16 Km north of Gainesville, Florida. The experimental site lies about 1 Km southeast of the farm headquarters, in a native flatwoods area. The site is bounded to the north, west, and south by lanes (roads), with a lane running north and south through the center of the site. There are 16 pastures varying in size from 0.648 to 0.714 hectares. A small intermittent pond is present in the northwest pasture. A creek approaches the site diagonally at the southeast corner (Figure 3.1.). Corrals and scales were located adjacent to the northwest pasture. Water tanks were located in all grazed pastures. There is a young slash pine (*Pinus elliottii*) plantation to the west and a mature longleaf pine (*Pinus palustris*) plantation to the south. A cultivated field (usually corn) lies to the north and a Mesic hardwoods (Magnolia and Bays) community to the east. The land is mostly level, but slopes to the east and south (approximately 2%) on the eastern side. All replications and most of the pastures are bordered by fire lanes. Abandoned logging roads course the area, starting in the two-month treatment, replication IV, the road forks, one going to the northwest corner and the other to the northeast corner of the site. The site had been burned in February 1974 and again in February 1976.

At the initiation of the experiment the soils classification of the area was a Leon fine sand, an Aeric Haplaquod. The site was reclassified 9 May 1978 into four different soils. Approximately 4% of the area is of the Myakka series

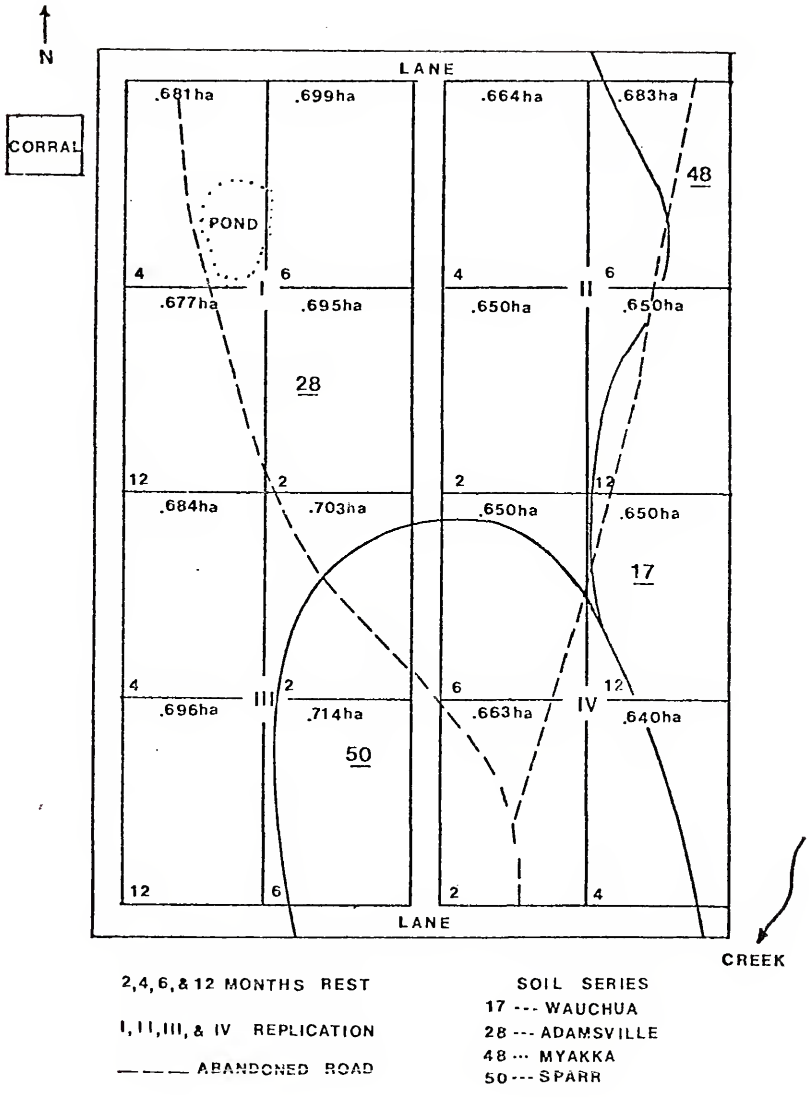

Figure 3. 1. Physical layout at the study site - BRU.

and 12% of the Wauchua series. Both of these soils lie to the extreme east of the site. The Sparr series comprises about 22% of the total area and lies in the central southern area. The remainder (62%) is of the Adamsville series and lies to the north and west (Figure 3.1.).

The Adamsville series is a member of the hyperthermic, uncoated family of Aquic Quartzipsamments. These are sandy soils having grayish A horizons and mottled grayish or brownish C horizons. The mean annual soil temperature at depths of 0.5 m below the surface is 22 to 23°C. These soils are on low, broad flats in lower Coastal Plains. Slopes are generally less than 2%. These soils are somewhat poorly drained. Soils range from very strongly acid to mildly alkaline. Permeability is rapid. The water table is at 0.5 to 1.0 m for two to six months during most years. It is at 0.3 to 0.5 m for periods of up to two weeks in some years. It is within depths of 1.5 m for more than nine months in most years. These soils were formerly classified as Regosols intergrading Low-Humic gley soils.

The Myakka series consists of deep, poorly drained soils formed in sandy marine deposits. These soils have rapid permeability in that A horizons and moderate or moderately rapid permeability in the Bh horizons. Slopes range from 0 to 2%. Combined thickness of the A and Bh horizons is more than 0.0 m. These soils range from extremely acid to slightly acid. The water table is at depths of less than 0.3 m for one to four months in most years, and recedes to depths of more than 1.0 m during very dry years. Depressions are covered with standing water for periods of six to nine months or more in most years. These soils were formerly classified in the Leon series as ground water podzols.

The Sparr series consists of somewhat poorly drained, moderately permeable soils formed in thick beds of sandy and loamy marine sediments. The subsoil is saturated in the summer, water runs off the surface slowly. Slopes range from 0 to 8%. Solum thickness is 1.5 m or more. Soils range from very strongly acid

to slightly acid in all horizons. The water table in these soils is at depths of 0.5 to 1.0 m for periods of one to four months. The water table is usually perched on the surface of the loamy layers. These soils were formerly classified in the Regosol great soil group.

The Wauchula series is a member of the sandy over loamy, siliceous, hyperthermic family of Ultic Haplaquods. These soils have a sandy dark colored A1 horizon and a sandy light colored A2 horizon that total less than 0.8 m thick over a Bh horizon and an underlying Bt horizon with low base saturation. These soils range from very strongly to strongly acid throughout. These soils are on level to nearly level areas of the lower Coastal Plain. They are poorly drained; slow runoff; moderately rapid or moderate permeability. Water table rises to depths of less than 0.3 m for one to four months during most years. It is at depths of about 0.3 to 1.0 m for periods ranging to about six months, but during the driest season it recedes to depths of more than 1.0 m. These soils were formerly included in the Leon series and classified in the Ground-Water Podzol great soil group. A more complete description of these soils is given in Appendix B.

Vegetation on the site is a typical flatwoods vegetation type as described by White (1973). The vegetation associated with a flatwoods is considered to be fire climax, due to the frequent natural occurrence of fire and the presence of fire adapted species (Laessle, 1942).

Pinus palustris was the dominant overstory tree, however Quercus incana is present in some numbers in the southern part of the area. The average basal area and canopy cover for the entire site is $6.47 m^2$ per hectare (ha) and 50.3%, respectively.

The predominant understory shrub is Serenoa repens, with an average canopy cover of 4.5%. Aristida stricta is the predominant understory plant with an average frequency of 13.6% for the entire area, however, its occurrence is considerably below this figure for most of replication III.

There were two distinct vegetation types on the site, a more mesic appearing vegetation was to the north and a more xeric type to the south. The ecotone between these two types was quite narrow lying between three and six meters across. Actual boundaries correspond very well to the soil map that was drawn based on soil cores (Figure 4.1.). A listing of some species found at the study site with common names and other miscellaneous information is presented in Appendix A, Tables A.2., A.3., and A.4.

A weather station is maintained by the University of Florida and IFAS at the BRU. A monthly summary of these data for rainfall, minimum and maximum temperatures are presented in Appendix A., Table A.5. Average long term weather data is not available for the BRU. The 70 year average for Gainesville will be used for comparison. The average annual temperature and precipitation for the Gainesville area are 21.2°C and 138.8 cm, respectively. This places the Gainesville area in the subtropical moist forest life zone classification system (Holdridge, 1967).

In 1976 the annual precipitation was 85% of normal and in 1977, 63%; the mean temperatures were slightly below normal (1°C), for both years. While the mean annual temperature was near normal the monthly means were below normal in the winter (January 1977) and above normal in the summer. The distribution of rainfall was similar, with more rain falling in the winter and less in the summer. On a three year comparison (1975 to 1977), the BRU appears to be about 1°C cooler (yearly average) than Gainesville. The precipitation is more erratic but is about the same as in Gainesville.

Man induced inputs are essentially in the form of mineral supplementation to the grazing cattle. This input, especially in the case of P, may represent a significant portion of the total P content in the soil profile (Chapter 13). Field practices used on the cornfield to the north of the site might have resulted in drift of material (fertilizer, lime, and dust) onto the site. There

is some evidence to support this (Chapter 14). Man was also responsible for burning the area in 1974 and 1976. However, since this is a "fire climax" (Laessle, 1942), no substantial changes in community structure should have been introduced by this factor. The fire lanes and the old logging roads did cause vegetational changes that are apparent. These areas have a greater preponderance of invader species (e.g. Rubus spp. and Paspalum notatum) than the main areas (Chapter 9). Other than the above effects, man's impact has been relatively minor.

Methods

Statistical treatment for this experiment was according to procedures given by Steel and Torrie (1960). A randomized complete block was the basic experimental design. The analysis of variance (ANOVA) was used to determine the "F" value and the means were separated by Duncans New Multiple Range Test. Where only two populations were being compared, a standard t-test was used. The level of probability was $P < 0.05$ unless otherwise stated.

Equations used for fitting data (regressions) were of three types, linear, multiple, and quadratic. The form of these equations are:

linear	$Y = a_o x + a_1$	(1)
multiple	$Y = a_o + a_1 z + a_2 x$	(2)
quadratic	$Y = a_o + a_1 + a_2$	(3)

Closeness of fit was determined by the coefficient of determination (r^2) (Steel and Torrie, 1960).

Diversity indices were calculated by the Shannon-Wiener equation (Shannon and Weaver, 1949):

$$H' = \sum (ni/N) \log(ni/N) \qquad (4)$$

ni is the total number for each specie and N is the total number of individuals.

The evenness component was calculated by:

$$J' = H'/\log s \tag{5}$$

where s is the total number of species present (Pielou, 1975).

The equation used to convert percent _in vitro_ organic matter digestibility (IVOMD), percent organic matter content of forage (OM), animal dry matter intake (IM) to digestible energy intake (DEI), was obtained from Dr. J. Moore, Professor, Animal Science, University of Florida, 1978. The equation for DEI (in Mcal/da/animal) is:

$$DEI = (IM)(M)(IVOMD)(4.4) \tag{6}$$

where IM is in Kg/day/animal, OM and IVOMD are in percent, and 4.4 is the conversion factor from Kg of dry forage matter to Mcal.

The equation to estimate dry matter intake (DMI) from fecal output (FO) and IVOMD was adapted from equations described by Morris and Kover (1970) and Mott (1973):

$$DMI = (100)(FO)/(100\text{-}\%IVOMD) \tag{7}$$

where DMI is in Kg/pasture, and FO is in Kg/pasture.

Soil samples were collected, placed in paper sacks, and air dried (25^{o}C) in the University of Florida Range Laboratory, then passed through a 850 micrometer (0.0331 in) screen (U.S. standard testing sieve #20). The sample was then sent to the Soil Testing Laboratory, University of Florida, for chemical analysis. The standard procedure used by the Soil Laboratory is a double acid extract as described by Nelson et al. (1953). Phosphorus was determined by the Murphy-Riley (1962) method. Other elements were determined by the Technicon Auto Analyzer, Atomic Absorption or Flame Emission, depending upon the element requested. Soil water pH was determined by a 1:2 soil to water ratio, stirred to form a slurry just prior to inserting the electrode. The procedures used by the University Soil Testing Laboratory are outlined by Sabbe and Breland (1974). Chemical analysis of soils are reported in parts per million (ppm).

The *in vitro* organic matter digestibility (IVOMD) used in this study is the two-stage technique developed by Tilley and Terry (1963), with modifications as described by Moore and Mott (1974, 1976). This procedure is the same as is used by the Animal Nutrition Laboratory at the University of Florida, a detailed description of the procedure is presented in Appendix C. Briefly, the procedure consists of weighing approximately one half gram of the ground sample into a 50 ml centrifuge tube, innoculation with rumen fluid, mixed with a buffered artificial saliva and incubation for 48 hours at 35°C. The second stage consisted of addition of HCl and pepsin then another 46 hours of incubation. The contents of the centrifuge tubes were then filtered through glass wool in a Gooch crucible, dried at 70°C and ashed at 500°C. The organic matter content was determined by ignition and the digestibility calculated. The rumen fluid was obtained from a steer maintained by the Animal Nutrition Laboratory, University of Florida. This steer was fed a constant diet of Coastal bermudagrass hay (*Cynodon dactylon*), soybean meal, minerals and vitamins, throughout the duration of the experiment. Results of the IVOMD are expressed as percent digestibility.

Samples for foliar analysis were placed in open beakers and oven dried at 70°C for 24 hours to remove moisture. A half gram aliquot of the sample was placed in a crucible, ashed in a muffle furnace at 500°C for four hours, cooled and weighed. Ten milliliters of 40% HCl were added to the crucible, followed by evaporation, cooling, addition of 3 ml of concentrated HCl, evaporation, cooled, addition of 13 ml 0.1 N, HCl and standing for 18 hours. The sample was then transferred and brought up to 25 ml volume, filtered and stored in plastic vials. The sample was then sent to the Soil Testing Laboratory for analysis. The analysis is basically the same as that described for soil samples after extraction by the double acid process. Chemical values for foliar content are reported in parts per million (ppm).

The amount of forage in each pasture prior to cattle entry was estimated by the use of clipped plots and a Neal Herbage Meter (Model 18-2000). Each pasture was traversed by four equally spaced transects running north and south. Each transect was divided into ten equally spaced sampling points. Each sampling point was permanently marked and numbered. The dimensions of the sampling quadrat and the herbage meter were the same, 0.186 m^2 (2 ft^2). Golf tees were used to mark the position of the legs of the herbage meter on the ground so that accurate positioning of the meter would be possible throughout the course of the experiment. There were 40 permanently marked quadrats.

Each quadrat was classified as to wet, dry, or moist, based upon the presence or absence of certain indicator species. The indicator species for wet were: Ilex coriacea, Amphicarpum muhlenbergianum, Panicum hemitonom, and Centella asiatica. The species used for dry site determinations were: Asimina spp., Anthaenantia villosa, Erecmochloa orphiuroides, Sporobolus junceus, Triplasis americana, Rhychosia spp., and Diodia teres. In the presence of any of the above species the quadrat was considered as wet or dry, respectively. In the absence of the above species the quadrat was considered moist. The pasture was partitioned into percent wet, dry, or moist, based upon the percentage of the quadrats in each category.

Initially, eight quadrats were to be clipped prior to cattle entry and again after leaving the pasture. This was reduced to four in November 1976 and raised to eight again in June 1977.

The procedure for determining the location of the clipped plots was as follows: The herbage meter was first calibrated to bare ground, then a meter reading was obtained for each permanently marked quadrat. The difference between the high and the low meter reading was divided by the number of quadrats to be clipped (four or eight). This interval (D) was then added to the lowest meter reading, the resulting value was then compared to the list of readings

taken for the pasture, the quadrat with closest meter reading to this calculated value was selected. Two intervals (2D) were then added to the lowest meter value, this new value was compared to the list and the closest matchup recorded. This procedure was followed (3D, 4D, etc.) until all quadrats to be clipped had been accounted for. In case two or more meter readings were equally distant from the computed value, selection was made on the basis of having each line represented by at least one clipped plot. This procedure gave a random selection for clipping, over the range of meter readings. The meter was then taken to the selected plot and the vegetative composition noted (ocular) of the permanent quadrat. A similar community was then selected close by, and the meter positioned until the same value was obtained as noted in the permanent quadrat. This plot was flagged and clipped. The permanent quadrats were not clipped during the course of the experiment.

Each clipped plot was sorted as to species (standing dead material was included), placed in paper sacks and marked as to specie, date, plot, and pasture location. Litter was also collected with large branches removed. The samples were then taken to the laboratory and dried at 70^{o}C for three days, and weighed. Species identification was double checked at this point. The samples were then stored at room temperature until needed. Two separate tallys were made, species and weights, and a grouping as to grazables, ungrazables, and litter with corresponding weights. Shrubs and trees were generally considered as ungrazables; *Aristida stricta*, other grasses, and most forbs were considered as grazables.

Linear regression equations were developed with the grazable portion, meter readings. and the average available forage calculated for each moisture type in the pasture. Based upon the percentage of each moisture type in each pasture total available forage was determined. Assuming 2.5% forage dry matter required 45.4 Kg (100 lbs) animal live weight, the number of animals

and the length of stay in each pasture was determined, assuming 50% utilization of grazable forage.

There were eleven animals available for use. Five or six animals were placed in each pasture, in an effort to keep the duration of grazing to six days or less (Mott, 1973). Consequently, grazing in all replications for a particular treatment was not simultaneous. The cattle were weighed prior to entry into each pasture and again upon leaving. The experiment was designed to run for one full year starting on 7 July 1976, however, due to delays in sampling and other aspects discussed in Chapter 9, the final sample was collected on 14 September 1977. Dates of sampling are presented in Appendix A, Table A.1.

CHAPTER 4

GENERAL SOIL STUDY OF THE SITE

Introduction

Nutrients cycle through ecosystems with the type of cycle depending on the nutrient of interest. There are generally two different cycles, complete and incomplete (Deevey, 1970). A complete cycle is one in which the element exists in all the major components of the earth; the atmosphere, lithosphere, hydrosphere and the biosphere. Nitrogen, carbon, sulfur, and oxygen are examples of complete cycles. Where one of the above components is essentially missing it is an incomplete cycle. Since, for all practical purposes, P does not volatilize it is considered as having an incomplete cycle. Along with energy flows, the cyclic nature of elements is responsible for the continued productivity of the worlds ecosystems and, in particular, allows fertilizers to be used to economic advantage (Curlin, 1970; Deevey, 1970; Golley, 1975).

A major factor in determining the quality and quantity of plants is the soil (Brady, 1974; Odum, E., 1971). However, in Florida, the sandy soils provide minimal nutrients in their natural state (Geraldson, 1977). In the native longleaf pine (*Pinus palustris*) forest of Florida nutrients cycle through the site from soil to tree to litter to soil, in a much simplified description of the actual cycle. In a mature stand it takes between eight and twelve years for a forest floor to reach stability with respect to litter buildup and decomposition, in the absence of fire (Heyword and Barnette, 1936). Laessle (1942) recognized that the natural pine flatwoods of Florida were dependent upon fire to maintain a certain stability, and described the forest as a fire climax.

Fire reduces the decomposition time and, in effect, speeds up the nutrient cycling of the system, thus altering the soil characteristics (Ralston and Hatchell, 1971).

Leithead (1973) has recognized seven woodland suitability groups in Florida that are of major concern. Of these, the flatwoods type soils occupy approximately one-half of the land area in Florida (Smith et al., 1967). These soils contain very low levels of available nutrients (Yuan, 1966; White and Pritchett, 1970; Pritchett and Smith, 1974). Phosphorus is believed to be the most limiting element in these soils (Yuan and Breland, 1969; Ballard and Pritchett, 1974).

Phosphorus does move in the soil, it is just that the amount moving is small, relative to the amount present (Thomas, 1970). The rate of loss by stream flow and leaching is not large; Duffy et al. (1978) reported an average of 0.027 ppm from five different watersheds in Northern Mississippi; Thomas, summarizing from streams flowing over high phosphate containing limestone, reports ranges from 0.09 to 0.22 ppm. The rate of movement of P is also dependent upon the amount of fertilizer applied (Rodulfo and Blue, 1970), and has been shown to be related to amounts of Fe and Al present (Yuan and Breland, 1960; Ballard and Pritchett, 1974). The loss of P from native systems in Florida can probably be considered minimal unless Fe and Al are in relatively low concentrations.

One avenue of loss that has not received too much attention is the loss associated with the removal of timber. Bole wood accounts for about 28% of the total P in slash pine (White and Pritchett, 1970). The actual amount of P removed would be a function of the total biomass removed from the site. Pulpwood production takes even a higher percentage of the total tree, and if the current trend toward total harvest continues, this figure will rise higher. There is some evidence that second growth pines do not do as well as first

growth unless fertilized (Pritchett, 1976). The above line of reasoning would indicate that unless some sort of fertilization is practiced, the fertility of these soils can be expected to decline with continued use.

Range grazing systems contribute relatively little to the loss of minerals (Pieper, 1974) and if minerals are supplied to the animals, grazing may represent a net gain (Chapter 13). Other forms of P input to the system are from parent material and atmospheric inputs. The parent materials in Florida are marine deposits of sand, with some phosphate bearing layers that are presently being mined and shipped to out-of-state locations, however, there is little P that is being added to Florida rangelands from this source. The atmospheric inputs of P are minimal (Chapter 13).

The effect of wind-throw on the redistribution of nutrients in a mature forest has been discussed by Lutz (1940); Goodlett (1954); and Drury and Nisbet (1973). This effect is probably minimal in Florida since there is little evidence that P accumulates at soil depth. Also the management practice of harvesting young trees for pulpwood rather than older ones for saw timber, would result in less trees susceptible to wind-throw.

Materials and Methods

Soil samples were collected from each pasture in April 1977. Three equal distant lines were set up in each pasture and five soil samples were taken along each line, at equal intervals. Samples were collected from three depths (0 - 10, 10 - 20, and 20 - 30 cm) with a 2 cm diameter soil core. Five separate cores were taken at each sample point and composited for each depth. A total of 15 composited samples were taken at each depth for each pasture, a total of 45 samples per pasture. The samples were analyzed at the University of Florida Soil Laboratory for pH, P, K, Ca, and Mg.

Statistical analysis of the results consisted of taking the average, standard deviation and CV at each depth for each pasture, for each of the six

soil parameters. These means were then used in a randomized complete block design and tested for replication and treatment effects. Pasture averages were calculated, using the total of all samples at three depths; analysis of variance (ANOVA) was also computed for each of the six parameters. Two different groupings of pastures were used in both of these analyses. The first was by grazing treatment and replication, the second was as to physical location of the pasture on the site.

In March 1978, additional soil samples were taken in replication IV (the control, and four-month rest). The entire 30 cm profile was sampled at one time; there were 15 replicated samples per pasture. A t-test was used to compare these results to those from the same pastures in the 1977 sample. All three depths at each sample location were composited in the 1977 samples, thus giving 15 values for the 30 cm soil profile.

To check on possible effects of trampling, bulk density determinations were made in February 1977 for replication I (the control and two-month rest). Fourteen samples were taken in each pasture. Each sample position was randomly selected. A t-test was used to analyze the results.

In April 1977 ground water wells were placed in all but the six-month rest pastures to measure evapo-transpiration rates and water quality. The wells were dug with a bucket auger and four 10 cm (4 in) diameter PVC pipes were positioned. The depth of the wells varied from pasture to pasture, depending upon the depth to the spodic horizon. The depths of the wells were such that this horizon was penetrated at least 5 cm (2 in). Three water level recorders were obtained to record fluctuations in the water table. The initial procedure was to have a recorder on each well in a replication for a period of one week; then moved to another replication. Two weeks after installation the wells dried up, except for two wells located on the east side of the site. These two wells went dry about a month later.

Each well was to have been sampled for water quality every two weeks after installation; again, the drying up of the wells precluded this. Consequently, only three samples were taken on an irregular basis, depending upon presence of water in the wells.

Differences noted in the soil profile during construction of the wells prompted a more detailed coring of the area. The main area of concern was the ecotone between the two vegetational sites, the dryer site to the south and the wetter to the north. Cores were taken to a minimum of 1.4 m (4.5 ft) until well within the spodic horizon; 36 cores were taken on both sides of this ecotone. Five representative cores were chosen and samples taken, starting with the surface, at 0.3 m (one ft) intervals until the spodic horizon was reached. These samples were analyzed for pH, P, K, Ca, and Al.

Results

Average soil parameter data for three different depths (0 - 10, 10 - 20, 20 - 30 cm) with coefficients of variations (CV) and results of ANOVA analysis are presented in Appendix D, Tables D.1. through D.6., for organic matter, pH, P, K, Ca, and Mg, respectively. Of interest is the extremely high CV recorded for P, an average of 109%, with ranges from 47 to 195%. Phosphorus had the lowest variation with an average CV of 6.8%. The other parameters were moderately active with average CV's in the 30 to 40% range.

The ANOVA analysis failed to show up any significant trend at any of the three depth levels for all components as a function of grazing treatment. A general trend was noted in that replication IV was usually lowest in nutrient content when the different averages were ranked, and replications I and II were generally higher. A different method of grouping for ANOVA analysis was made (not shown); this grouping reflected the actual physical location at the site. Again, no meaningful results were noted. When the averages were ranked, there

appeared to be a general decline in all parameters from the north to the south and also from the west to the east.

The analysis of the average soil content (all three depths composited for each pasture) was conducted with two different groupings of the pastures (physical location and by treatment and replication). This analysis showed trends similar to that observed for each soil depth. When the pastures were grouped as to their physical location (Table 4.1.), all components except P and pH had higher values along the corn fields to the north. Both Ca and K were different at the $P < 0.05$ level. No column effects were found to be significant. However, all components except Mg were lowest in those pastures on the east side (nearest the creek).

The ANOVA analysis, based upon grouping the pastures as to grazing treatment and replication (not shown), indicated meaningful treatment and replication effects for K and organic matter. The four-month and the control were higher in K than the other treatments. Organic matter was highest in the four-month treatment. Replication I had the highest levels of K and organic matter. The other components (except P) were also higher (not different at the $P < 0.05$ level) in replication I, generally followed by replication II.

Efforts to relate, through linear regression (eq. 1), the different soil components failed to arrive at a meaningful coefficient of determination (r^2). The highest r^2 computed was 0.32 for Ca and Mg at the 20 to 30 cm depth. All other comparisons yielded r^2 values less than 0.27.

Due to the high variation within and between pastures, an effort was made to determine which of the four replications were most alike, with respect to the different soil parameters. A t-test was used on a replication by replication comparison using the average value of each component for each pasture, and on various groupings of replications. The basis of selection was that there was not a difference at the $P < 0.1$ level. The result of this comparison

Table 4.1. ANOVA analysis, based on the pastures actual physical relation to one another, for average soil data.

	Column				$\overline{X}$
			Organic matter (%)		
N					
Row	3.7	2.7	2.3	1.7	2.6
	2.7	2.0	1.3	1.3	1.8
	2.3	1.7	1.7	2.0	1.9
	1.7	1.7	1.7	2.0	1.8
$\overline{X}$	2.6	2.0	1.8	1.8	
	Row F = 2.865 (ns)		Column F = 3.115 (ns)		
			pH		
Row	4.47	4.33	4.30	4.33	4.36
	4.53	4.63	4.77	4.30	4.56
	4.53	4.73	4.80	4.13	4.55
	4.90	4.43	4.47	4.17	4.49
$\overline{X}$	4.61	4.53	4.59	4.23	
	Row F = 0.959 (ns)		Column F = 3.422 (ns)		
			P		
Row	1.7	2.7	4.1	1.7	2.6
	3.8	8.3	8.4	1.5	5.5
	6.7	4.3	4.6	0.5	4.0
	12.9	10.9	2.1	0.9	6.7
$\overline{X}$	6.3	6.7	4.8	1.2	
	Row F = 1.217 (ns)		Column F = 2.319 (ns)		

Note: Numbers followed by same letters or absence of a letter are not significant at the $P < 0.05$ level. F values followed by ns are not significant at $P < 0.05$ level, other entries indicate the level of significance.

Table 4.1. - continued

		Column				$\overline{X}$
			Ca			
N						
		154	141	120	123	134a
	Row	124	109	103	102	110
		79	129	102	73	96
		111	102	98	98	102
	$\overline{X}$	117	120	106	99	
		Row F = 5.249 (.025)		Column F = 1.797 (ns)		
			K			
		11.7	9.3	8.0	8.7	9.4a
	Row	8.0	6.3	6.0	5.7	6.5
		6.0	6.3	8.3	5.0	6.4
		5.3	5.7	5.7	6.7	5.9
	$\overline{X}$	7.8	6.9	7.0	6.5	
		Row F = 6.426 (.025)		Column F = 0.651 (ns)		
			Mg			
		30.3	18.7	13.7	13.7	19.1
	Row	14.7	11.1	9.0	11.0	11.5
		7.7	13.7	8.7	9.3	9.9
		8.3	7.7	9.7	13.7	9.9
	$\overline{X}$	15.3	12.9	10.3	11.9	
		Row F = 3.664 (ns)		Column F = 0.810 (ns)		

(not shown) indicated to this investigator, that replication I and II were the best combination to use for Ca, K, and Mg, and replication I and III were the best combination for P, pH and organic matter.

The comparison between the four-month rest and the control in replication IV for P, Ca, and K for the April 1977 collections and the March 1978 collections showed an increase in all three components (Table 4.2.).

The bulk density of the two-month treatment in replication I was 1.38 g/cc and that in the control was 1.29. This was not different at the $P < 0.05$ level.

Two water level recorders were set in position on 1 May 1977, in replications II (four-month rest treatment) and in replication IV (control). Five days later the well in replication II went dry. The well in replication IV went dry on 4 June 1977. The rate of discharge was computed to be 0.7 cm per day for both wells. The water level in both wells was over a meter from ground surface when the recorders were set up. The water level recorder trace made by the well in replication II was a stepwise function, but could not be construed as a daily transpiration pattern due to irregular fluctuations. The trace in replication IV was smooth.

On the afternoon of 8 May 1977, 3 cm of rain fell. The exact time is not known since only one collection of weather data is made per day (8:00 a.m.) at the BRU farm. At 4:30 a.m. on 9 May, the water level in replication IV started to rise and 7.2 hours later the level in replication II started to rise. Six days were required before the levels in each well returned to their original levels. The rate of water movement through the soil was calculated to be about 18 m per hour. This same kind of water level increase was noted on two other occasions, 27 May and 25 June. In both instances the amount of precipitation was greater than 2.5 cm and again there appeared to be a lag from the time the rain fell to when the recorder measured an increase. The

Table 4. 2. Comparison of soil data collected in April 1977 with that collected in March 1978 for P, Ca, and K.

	P		Ca		K	
	1977	1978	1977	1978	1977	1978
			4 month rest			
$\bar{X}$ (ppm)	0.83	2.23	97.5	140.0	6.3	12.0
s (ppm)	0.78	0.97	27.2	35.1	2.1	5.9
CV (%)	94.20	43.70	27.9	25.1	33.6	48.9
Level of Significance (P<)	.001		.001		.010	
			Control			
$\bar{X}$ (ppm)	0.46	1.77	72.9	113.4	4.9	8.9
s (ppm)	0.41	0.66	13.0	29.3	1.2	2.3
CV (%)	89.60	37.10	17.8	25.8	23.7	26.1
Level of Significance (P<)	.001		.001		.001	

well in replication II was abandoned on 23 May and that in replication IV on 30 June 1977. Due to the muddy condition of the water in the well, and the general low level of water, samples were taken for three dates in May only. The P content was less than 0.05 ppm, K was 0.6, and Ca 2.75 ppm.

Based on the results of the soil cores, two separate soils were determined to exist on the site. Sample profiles of each type taken approximately 30 m apart are shown in Figure 4.1. Table 4.3. shows the average values for pH, P, Ca, K, Mg, Fe, and Al, for the two types based on depth from the surface. Since the intervals where samples were obtained did not necessarily fall in the same horizon in the two different soils, the only comparison made was with the spodic horizon. The spodic horizon occurred at about 1.5 m (5 ft) in the wet type (soil lying to the north) and about 1.4 m (4.5 ft) in the dry type (soil lying to the south). The spodic horizon in the wet type was of a sandy nature and that in the dry was more clay-like which is reflected in the high Al content in the spodic horizon of the dry type soil (Table 4.3.). The dry type spodic horizon also had a mottled appearance with visual evidence of iron.

A <u>t-test</u> indicated that there was a higher ($P < 0.05$) Fe and Al content in the spodic horizon of the dry site than the wet site. The content of Mg and K were found to be higher ($P < 0.01$) in the dry site. P, Ca, and pH were not found to be different at this level. A linear regression (eq. 1) was used to relate soil P to soil Al and an r^2 of 0.32 was obtained. A multiple regression (eq. 2) with Al and Fe as the independent variables resulted in an r^2 of .502.

Coring on both sides of the ecotone determined that vegetational differences were associated with the different soil types. Figure 4.2. delineates the boundary between the two different soil types. Coring was not conducted on the vegetational differences noted along the far eastern side since this difference was believed to have been due to a moisture gradient rather than soil differences.

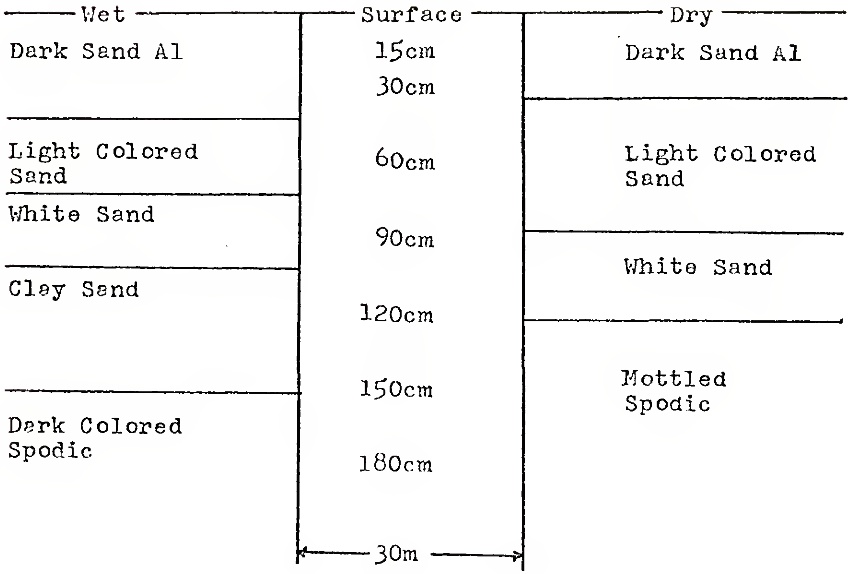

Figure 4.1. Soil profile of the wet and dry sites along vegetational ecotone.

Table 4.3. Analysis of various soil components for the wet (Adamsville Series) and the dry (Sparr Series) taken near the interface of the two soil groups.

Depth (m)	Component						
	pH	P (ppm)	Ca (ppm)	K (ppm)	Mg (ppm)	Fe (ppm)	Al (ppm)
				Wet (Adamsville)[a]			
Surface	4.1	2.4	170	9.9	18.0	450	141
.305	4.4	4.4	94	4.0	2.9	327	285
.610	4.5	2.7	86	1.6	2.4	233	273
.914	4.6	2.1	80	0.7	3.2	187	142
1.219	4.7	1.0	70	0.6	2.4	143	53
1.524	4.9	0.8	86	0.8	2.4	153	42
1.829	4.9	1.95	85	0.8	4.0	120	45
2.134	5.1	0.5	100	1.6	3.2	170	16
				Dry (Sparr)[b]			
Surface	4.6	11.1	140	6.6	10.8	480	230
.305	4.9	4.9	91	3.0	4.4	345	277
.610	4.8	3.0	83	1.0	4.4	295	223
.914	4.8	2.7	88	0.8	4.0	265	130
1.219	4.1	2.4	87	2.6	6.6	405	263

a. 3 sample average
b. 2 sample average

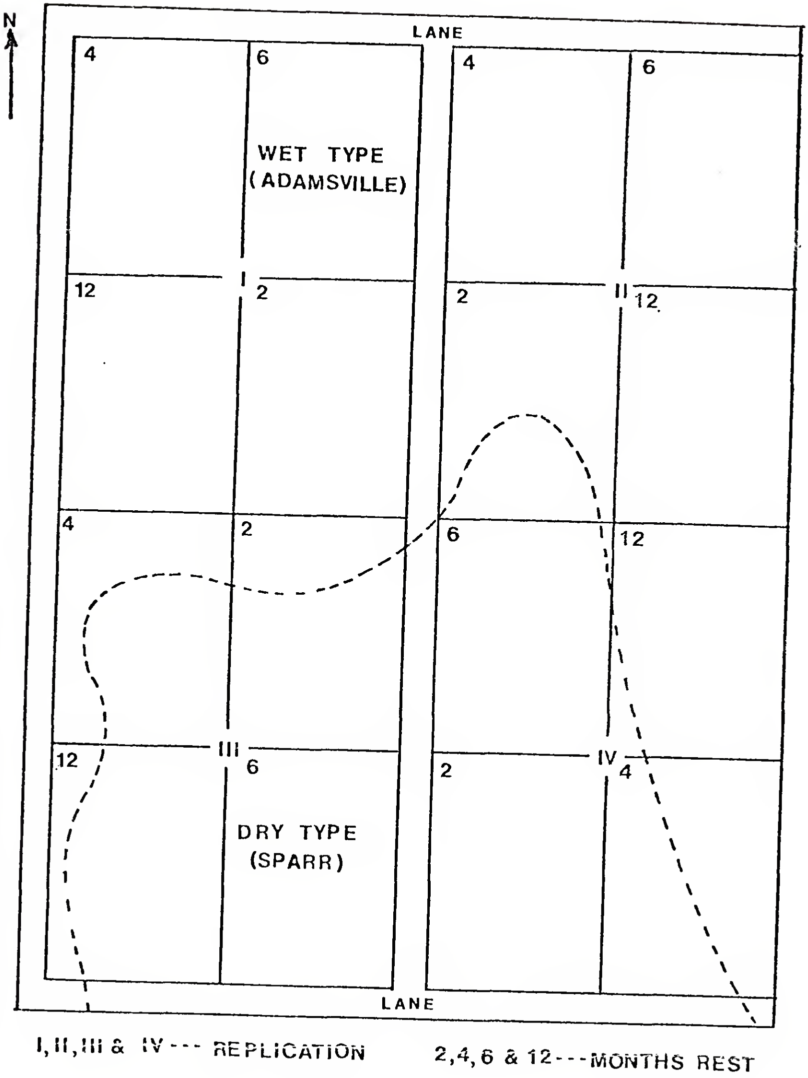

Figure 4.2. Soil map based on soil cores showing boundary of the two different soil types.

The soil survey that was made available on 9 May 1978 (Chapter 3) defines the wet soil as an Adamsville series and that of the dry type a Sparr series. The boundaries drawn from this survey conform to the boundaries determined in this study.

Discussion and Conclusions

The high variability of the P content of these soils is believed to be associated with the low amount of P noted and is a real phenomenon that occurs on sandy flatwoods soils. A discussion of this variability is delayed until the conclusion of Chapter 6 (micro-variability).

The general trends noted appear to be associated with the physical location of the pastures at the study site, rather than the treatments that were imposed upon them. The major reasons are the field practices used in the cornfield to the north, the presence of the creek to the east, the four different soils present in the site and the manner of distribution, the length of time required for fecal material to move into the soil profile (Chapter 11), the irregular weather pattern that existed during the experimental phase (Chapter 3), the apparent slowdown of the general decomposition process due to the cold weather and the lack of moisture, and the relatively short period of time the experiment had been in progress prior to soil sampling.

There also appear to be effects that are not explained by the data gathered. In particular, the increase noted in the soil chemical content that were sampled in March 1978. This increase was noted in two pastures and was not apparently related to treatment. However, there were only two pastures sampled, and the method of sampling was slightly different; whole cores being used rather than the average of three separate depths. This difference in sampling procedure might account for the differences noted. In the absence of replications, it is impossible to draw a conclusion.

Failure to obtain any relation between any of the soil parameters may be due to the parameters that were compared and the method of comparisons rather than a lack of relationship. Had a multiple regression (eq. 2) been used, a better correlation might have been forthcoming. This is, in part, borne out by the comparison of P with Fe and Al (eq. 2) and the resulting r^2 of 0.502. This correlation is less than that reported by Yuan and Breland (1960). These authors reported r^2 values of 0.76 or higher for spodosols in a multiple regression with Fe and Al as the independent variables. Only 13 samples were available for comparison in this study. Future studies should report the Fe and Al levels since these have been linked to P retention in Coastal Plain soils (Ballard and Fiskell, 1974).

The results of the soil cores, delineating the boundary of the two vegetational types into two distinct soil types (Adamsville and Sparr) were borne out by the later soil survey of the area. The boundaries determined in this study are somewhat different than those reported by the soil survey. This difference is explained by the sampling techniques used by the survey team. Samples are taken over an area at intervals of about 91.4 m (300 ft) or greater. Consequently, the position of the boundary has this built-in variation. The boundaries defined in this experiment (Figure 4.2.) lie well within the range of precision of the survey team.

The recommendations made as to which replications are most alike are very general in nature and are offered as guides for later comparisons. Almost any combination could have been made with some kind of justification, depending upon which soil component was of interest. In the opinion of this investigator, replication I and II are most alike with respect to Ca and K, and replications I and III with respect to P.

Considerable effort had gone into the installation of the wells in the hope that evapotranspiration rates could have been measured, along with water quality. The drying up of these wells precluded the accumulation of this type of data. It does appear that ground water recharge does occur from the adjacent creek, and that rainfall of the order of 2.5 cm is required before this effect is noted. There also appears to be a time lag associated with the time of rainfall and the time that it appeared in the soil water table. Observations of the wells indicate that the wells on the western side of the site were the first to go dry, the eastern side last. Chemical analysis of the water samples were in general agreement with those reported in the literature.

The dry site (Sparr) has a clay type hardpan or spodic horizon lying above the spodic horizon of the wet (Adamsville) soil. These two effects combine to form the dryer site. Ground water moving from the creek would tend to flow underneath the Sparr soil. Thus, the plants on the Adamsville soil would have water available to them longer than those on the Sparr soil. The clay horizon acts as a barrier to root penetration and upward movement of any water below this depth. This horizon would not be expected to be equally continuous, and fractures or ruptures (possibly caused by wind-throw) would allow areas or islands of wetter vegetation to exist side by side with the dryer types. This island effect was observed on the Sparr soil.

The low levels for P at this site are not unique for Florida flatwoods. Pritchett and Smith (1974) reported a P content of 0.2 ppm for a site prepared, but unfertilized, flatwoods site in site in Western Florida. Rudolfo and Blue (1970) reported a P content of 48 ppm on a virgin flatwoods area at the BRU; they did not report on the vegetative cover present at the time of sampling. Koger et al. (1961) report 15.7 Kg/ha of P present in an open young longleaf pine stand, similar in appearance to that at this site, except that the trees are much smaller. Using a bulk density of 1.31 g per cc, and procedures given

in Brady (1974), this converts to a 7.9 ppm of soil P. Numerous references exist for the general low content of P in Florida flatwoods soils (Yuan, 1960; White and Pritchett, 1970).

Phosphorus is generally considered to be limiting on most of these flatwoods areas (Yuan and Breland, 1960; White and Pritchett, 1970). Since P is known to increase as the standing biomass increases (Rodin and Basilevich, 1965), there have been efforts to develop equations predicting the amount of nutrients present in trees (White and Pritchett, 1970). These equations relate the amount of P present as a function of size of the tree.

Since size of the tree is a function of age, the amount of P in the overstory is also correlated with age of the stand (Curlin, 1970). Unless P was being obtained from the parent material or other sources faster than it was being taken up by the vegetation and stored, there would be a net decline in P availability as the stand matures. This would continue until the system attains an equilibrium, as much new biomass and hence P, added as was deposited as litter (Grier and Logan, 1977). This implies that a native flatwoods site would become progressively less fertile as the trees on it grow to maturity.

Harvesting the tree overstory also represents a drain on the available nutrient supply, unless fertilization is practiced. The flatwoods of Florida have been cut over at least once and perhaps more; old stumps in the study site attest to this. There is reason to believe that the flatwoods were once more fertile than they are at present. A possible line of inquiry would be to determine whether if, in fact, soil fertility is related to age of stand of timber and to determine this rate of decline.

This potential decline in soil fertility has implications for all aspects of range management. There is reason to believe that the quality of the native plants growing on these sites is not as high as those growing on different soils

(Chapter 8). Forage quality with respect to deer foods indicate that the herd size is much less than would be expected from a consideration of the plant biomass alone (Chapter 10). The livestock and the timber industry would also be affected. More effort should be directed toward relating soil fertility and forage quality for Florida conditions.

CHAPTER 5

CHANGES IN THE CHEMICAL CONTENT OF SOIL SAMPLES

Introduction

Soil samples are commonly stored in paper sacks and air-dried at room temperatures prior to analysis. Other methods of handling samples include sun-drying, oven-drying, or refrigerating in plastic bags. Extreme methods include oven-drying samples at temperatures in excess of 200^{o}C and even placing samples in frying pans on a heating element to speed the drying process. A sample often is inadvertently re-wetted by rain, dried, and then submitted for analysis.

Reports in the literature on changes in chemical properties of soil as related to different treatments of the sample are generally restricted to the analysis of nitrogen and phosphorus. For example, oven-drying and crushing soil samples (McKenzie and Kurtz, 1976) increased the accessibility of the energy source for the denitrification process. Organic matter (Brady, 1974) influences physical and chemical properties of soil far out of proportion to its low content in the soil. The amount of organic material (Birch, 1959) that is extracted from a soil sample by water increases as it's storage time in the air-dried state lengthens. Lebedjantzev (1924) used the increased availability of nitrogen and phosphorus after wetting a dry soil to explain the apparent growth response of plants following a rain. Stevenson (1965) observed a higher metabolic activity after air-drying and re-wetting a soil sample. Birch (1960) noted that extra nitrogen was available upon moistening the soil sample.

Mesophiles are most of the soil microflora, while thermophiles are generally restricted to soils that receive additions of composted material (Dickinson, 1974). Optimum temperatures range from 25°C to 37°C for the growth of mesophiles and from 55°C to 65°C for the growth of thermophiles (Dickinson, 1974). Mesophiles should undergo stress as environmental temperatures approach 35°C and experience increasing mortality as temperatures continue to rise. Many proteins are denatured as the temperature approaches 50°C (Leopold and Kriedeman, 1975). Consequently, various organic substances are released and are available for chemical combination with soil particles as the temperature increases.

The objectives of this study were (1) to assess changes in chemical properties of a Sparr sand as affected by treatment of the sample prior to analysis and (2) to define a procedure for handling field-moist samples from this and related soils of Florida.

Materials and Methods

A composited soil sample, the surface 10 cm of Sparr sand at the BRU, was collected and placed in a large plastic bag. The sample was sieved, mixed and split into 50 sub-samples. Groups of 10 samples each were randomly selected for each of the following treatments: samples refrigerated in plastic bags at 6°C; air-dried in paper sacks at 25°C; oven-dried in beakers at 36, 69, or 105°C for five days. All samples were then placed in plastic containers until analysis. The following components were determined: pH, P, Ca, K, Mg, Fe, and Al. Percent organic matter expressed as air-dry basis, was determined by sieving and mixing ten samples from the original bulk sample and ashing at 500°C.

After initial analysis, three groups of samples (air-dried, oven-dried at 69°C, and oven-dried at 105°C) were taken and wetted with distilled water

and allowed to stand for 24 hours. Each group contain ing the same ten sub-samples as in the initial run was then dried for five days at the same temperature as it had previously been dried, and analyzed as indicated above.

Statistical analysis utilized a completely random design to determine significant differences at the 0.05 level. Duncans New Multiple Range Test was then used to separate the means. Coefficients of determination (r^2) and coefficients of variability (CV) were determined. Regression analysis was attempted to determine the best possible fit of the data.

Results

Results of the analysis for each group of samples are presented in Table 5.1. With the air-dried temperature (25°C) as the control, there was no significant difference at the 36°C drying temperature; phosphorus and iron had significant changes at the 69°C temperature, all elements showed significant changes at the 105°C temperature and pH, potassium and iron were significantly different at the 6°C temperature.

Quadratic regression (eq. 3) were constructed from the above data with the resulting coefficients of determination (r^2); 0.969 for phosphorus, 0.965 for potassium, 0.958 for calcium, 0.971 for magnesium, 0.995 for iron, 0.945 for aluminum, and 0.945 for pH. The derivative of each equation, except pH, was taken and set to zero and solved for the maximum or minimum. The predicted minimum for phosphorus was 33°C and that for iron 18°C; the maximums for calcium, magnesium, potassium, and aluminum were 34, 36, 58, and 28°C, respectively. Figures 5.1. and 5.2. illustrate the predicted curves, and the maximums and minimums for each of the above elements.

The effects of taking three of the above samples, air-dried (25°C), oven-dried at 69 and oven-dried at 105°C, wetting and re-drying at the same temperatures as before are given in Table 5.2. With air-dried as the control, all components showed a significant difference when compared to the 105°C

Table 5.1. pH and some extractable elements of a Sparr sand as a function of drying temperature.

Characteristic	Drying temperature, °C				
	6	25	36	69	105
pH	4.90	4.63a	4.64a	4.58a	4.10
CV (%)	1.3	1.9	1.4	1.7	3.5
Phosphorus (ppm)	6.0a	5.6a	5.8a	7.0	23.4
CV (%)	19.5	7.5	6.4	14.4	5.1
Potassium (ppm)	7.5	9.6ab	9.4a	10.2b	8.2
CV (%)	8.8	6.9	10.9	7.3	4.9
Calcium (ppm)	209.0a	202.0a	211.0a	207.0a	151.0
CV (%)	3.9	6.4	5.6	8.0	7.0
Magnesium (ppm)	40.8a	41.1a	42.0a	40.8a	30.2
CV (%)	3.2	4.2	4.3	8.4	2.9
Aluminum (ppm)	244.0a	222.0ab	254.0a	225.0b	157.0
CV (%)	5.6	7.4	5.6	7.7	4.6
Iron (ppm)	23.7	26.1a	25.8a	32.7	54.0
CV (%)	7.4	1.9	1.0	3.0	2.8
Organic matter (%)[1]	1.5	1.5	1.5	1.5	1.5
CV (%)	3.2	3.2	3.2	3.2	3.2

1. Organic matter was determined from the original composite sample.

Note: Entries followed by the same letter are not significantly different at the ($P < 0.05$) level.

$$pH = 4.84089 - 0.00312X - 0.00003X^2$$

$$Mg = 39.0705 + 0.1841X - 0.0025X^2$$

$$Fe = 25.5338 - 0.1439X + 0.0039X^2$$

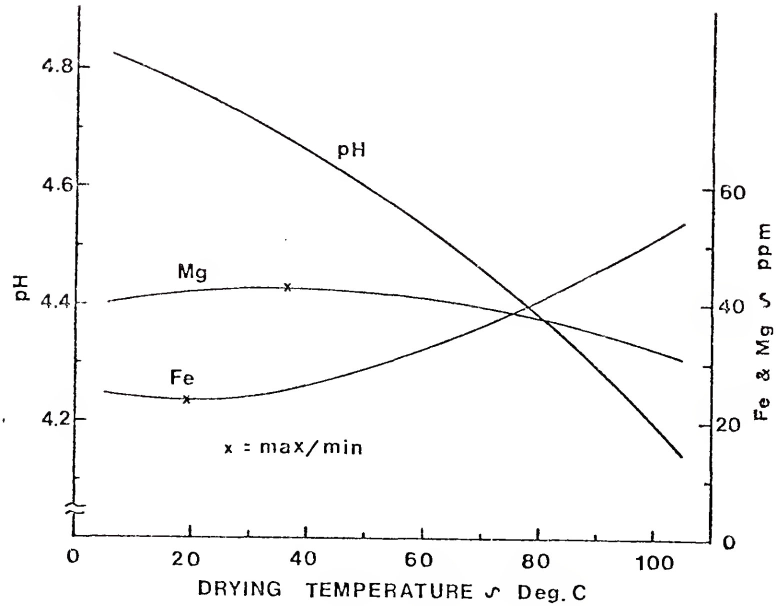

Figure 5.1. Change in chemical analysis for Fe, Mg, and pH as a function of drying temperature.

$$Al = 231.1489 + 0.8652X - 0.0148X^2$$

$$Ca = 198.2835 + 0.8360X - 0.0120X^2$$

$$K = 6.9693 + 0.1121X - 0.0010X^2$$

$$P = 8.3677 - 0.2393X + 0.0036X^2$$

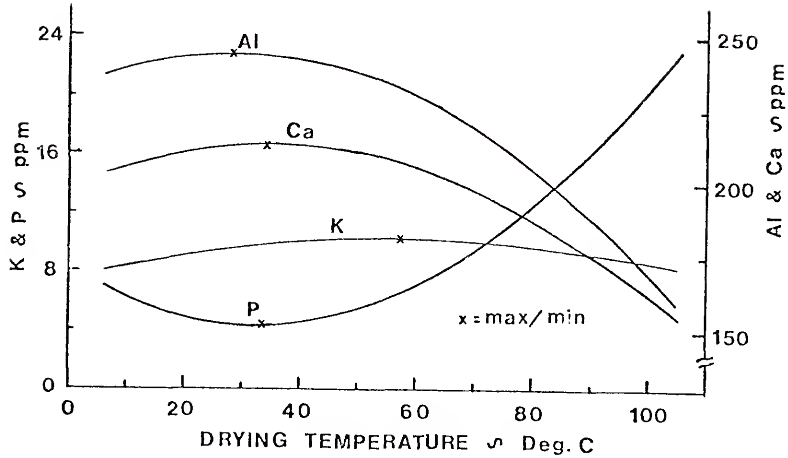

Figure 5.2. Change in Al, Ca, K, and P as a function of drying temperature.

Table 5.2. pH and some extractable elements of a Sparr sand after wetting and re-drying the original samples.

Characteristic	Drying temperature, °C 25	69	105
pH	4.72	4.31	3.94
CV (%)	0.9	3.0	1.2
Phosphorus (ppm)	7.2	10.7	21.6
CV (%)	18.6	10.3	6.9
Potassium (ppm)	8.8a	9.5a	7.1
CV (%)	4.6	12.7	9.9
Calcium (ppm)	189.0a	201.0a	155.0
CV (%)	5.9	17.8	8.8
Magnesium (ppm)	39.7a	39.4a	33.6
CV (%)	2.1	8.0	5.7
Aluminum (ppm)	230.0	219.0	165.0
CV (%)	2.9	4.0	4.9
Iron (ppm)	21.0	32.3	46.5
CV (%)	3.6	3.9	3.3

Note: Entries followed by the same letter are not significantly different at the ($P < 0.05$) level.

drying temperature; when compared to the 69°C temperature, pH, phosphorus, aluminum and iron demonstrated a significant difference. Table 5.3. presents levels of significance and amount and direction of change (using the original analysis as base), due to the effects of wetting and re-drying the sample. The change in calcium was not meaningful at the 69 or the 105°C temperature. The other components showed changes at some probability levels at both 69 and 105°C temperatures.

Discussion and Conclusions

The high coefficients of determination (r^2) of fitted quadratic equations for the elements and pH suggest that observed differences at the various drying temperatures are a product of one or more natural mechanisms. The time (five days) that the samples were kept at their respective temperatures allows ample time for biological mechanisms to manifest themselves. There is an interactive effect between decreasing moisture and optimum temperature for growth, but the time lag for moisture depletion appears sufficient for some metabolic activity to occur, especially at the lower temperatures. It is noted that the predicted minimum for phosphorus and for calcium and magnesium occur in the range of optimum mesophile growth (Dickinson, 1974). Therefore, possibility exists that phosphorus uptake at these temperatures (30 - 37°C) fixes the element in a slightly less soluble form, thereby reducing the amount shown in the analysis. At higher temperatures this would not occur, as death and/or inactivation of the mesophile is more rapid due to dessication and high temperatures. The low phosphorus content of the soil and the small changes noted would tend to magnify any such fixation by various organisms.

A Sparr sand is a loamy, siliceous hyperthermic grossarenic paleundult, has a Bh horizon and is poorly drained. Appendix B gives a detailed description of this soil series. At the time of collection the water table was at a depth

Table 5.3. The change from the original analysis (Table 5.1) and level of significance, as a result of wetting and re-drying the original samples.

Characteristic	Drying temperature, °C		
	25	69	105
pH	0.090	-.270	-.160
Level[1]	0.020	0.001	0.010
Phosphorus (ppm)	1.600	3.700	-1.800
Level[1]	0.001	0.001	0.020
Potassium (ppm)	-0.800	-0.700	-1.100
Level[1]	0.010	0.020	0.001
Calcium (ppm)	-13.000	-10.000	3.000
Level[1]	0.050	ns	ns
Magnesium (ppm)	-1.400	-1.400	2.400
Level[1]	0.050	0.400	0.001
Aluminum (ppm)	8.500	-6.000	8.000
Level[1]	0.020	0.400	0.050
Iron (ppm)	-5.100	-0.400	-7.500
Level[1]	0.001	0.400	0.010

1. Refers to level of significance.

of two meters, due to the unseasonably dry conditions that existed in Northcentral Florida in 1977. A possible physical scenario to explain the results noted might be as follows: Some of the sulfides should be oxidized to sulfate as the sample is dried. Moreover, the amount of sulfate should be significantly higher in a sample dried at 105°C than in one dried at 69°C. The sulfate should combine with Fe and form hydrolytic acidity in an aqueous suspension. These reactions would explain the decrease in pH and the increase in content of extractable Fe and P (Table 5.1. and 5.2.) between a sample dried at 69°C and at 105°C. Exchange sites are probably destroyed by heating at 105°C and exchangeable cations are possibly converted to insoluble forms. The amount of extractables Al, Ca, and Mg (Table 5.1. and 5.2.) is significantly lower in a sample dried at 105°C than in one dried at 69°C. Apparently, the amount of hydrolytic acidity generated in an aqueous suspension of a sample dried at 105°C was insufficient to dissolve the converted forms of exchangeable Al, Ca, and Mg. The possibility of the oxidation of sulfides to sulfate and subsequent combination with Fe to form a hydrolytic acidity in an aqueous suspension, might explain the differences.

Sulfide content of the samples was not determined, however, Neller (1959) reported in an analysis of 18 Florida soils 2 ppm of extractable sulfate in the top 9 cm. Mitchell[3] (1978, unpublished data) has found an average of 7.6 ppm of total sulfur in surface (13 cm) soils around the Gainesville area, all of which lie in the organic mantle. Neller (1959) found that sulfur leaches rapidly downward, due to the extremely low clay content of these Florida sands. Whether the low content of sulfur and related compounds found in Florida soils is sufficient to cause the proposed reactions remains to be tested.

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3. Mitchell, R. 1978. Graduate student, Univ. Fla., Soil Sci. Dept.

Changes that occurred upon wetting the sample and subsequent drying appear to be a continuation of the above mentioned processes. The water would provide a medium for reactivation of the biological processes at the lower temperatures and dispersal of organic acids. Hydration of the various oxides also occurs along with another mixing prior to drying.

A final possibility exists that because this soil contains very low levels of the elements studied, small changes, that might go unnoticed in more fertile soils, take on a significance that might be a result of the sampling or testing procedures. However, these differences are suspected to be manifestations of mechanisms that occur in many soils, but are only more noticeable in soils of low fertility. More experimentation on different soil types are indicated.

Different drying temperatures and the wetting and re-drying of soil samples causes significant changes in any subsequent chemical analysis. However, several chemical properties of surface samples of a Sparr sand and related soils in Florida should not be significantly affected by treatment prior to analysis if field-moist samples are transported in closed plastic bags and dried quickly between 25°C and 36°C and analyzed as soon as possible. If the treatment of the sample deviates from this procedure, details of the actual treatment should be reported along with the data.

CHAPTER 6

MICRO-VARIABILITY AND ITS EFFECTS ON SOIL NUTRIENT CONTENT

Introduction

The physical and chemical properties of the soil show small scale variations that may be as significant to the plant as it is unwelcome to those who make measurements on soils (Whittaker, 1975).

The present study was initiated after the main study had been completed and all data collected. In the analysis of the main body of soil data it soon became apparent that there was a great deal of variation associated with the different soil nutrients. The large coefficients of variation did not fit well with the notion that this site was a fire climax site and as such should have a climax soil type.

The analysis of different methods of handling soil samples, discussed in the previous chapters, allowed for some variation due to handling methods of samples prior to chemical analysis. However, all soil samples were handled essentially the same in the preceeding chapters. Other possibilities were examined, errors arising in the analysis, various human errors, but all were discarded as either being consistent, or too small to account for the large variations noted.

Gravity moves nutrients from higher elevations to lower, this is attested by the general observation that valleys are more fertile than the side hills. There is no reason why this same mechanism does not act similarly on a smaller scale. Water infiltrating into a relatively homogeneous soil is known to have a lateral movement (Amorocho, 1967; Branson et al., 1972). Sinai and

Zaslavsky (1977) studied the effects of lateral flow in soils that had been wetted (rainfall and sprinkler) and noted non-uniform patterns of wetting in the soil profile. Simulation models were made and predictions verified on cultivated fields in Israel (Sinai and Zaslavsky, 1977). The major factor thought to be contributing to the lateral flow was the anisotropic conditions found in cultivated soils as a result of plowing and mixing of the soil profile. The water movement appeared to be confined to the top layers of the soil, and was more pronounced in these layers if there was a slope present.

The hypotehsis is advanced that part of the variation noted in the soils at the BRU are due to this dilution of nutrients in the small elevations and the accumulation of these nutrients in the depressions.

Materials and Methods

On 13 March 1978 the control (no grazing) pasture in replication IV was sampled to determine effects of micro-relief on chemical content found in the soil. An area was selected that had visual evidence of relief and a transit positioned and leveled. The line lay 130°E. of N. on an easterly slope of 1.2% fall. A stadia rod was used to measure elevation. The interval of horizontal distance was 15 cm (6 in), 20 vertical measurements (elevation) were made for a distance of 6 m. At each point vegetative species were noted and soil samples from two depths (0 - 10 and 10 - 20 cm) were collected. The soil group at this particular site was a Wauchula series (Appendix B).

Soil samples were collected directly under the stadia rod by a 2 cm diameter soil core and stored in plastic bags (two cores were taken and composited for each depth). They were immediately taken to the Range Laboratory, weighed, dried at 70°C for 48 hours, re-weighed and percent moisture determined. Each sample was split into two equal portions. One half was weighed, placed in a muffle furnace at 500°C for four hours, weighed and percent organic matter

calculated. The other half was sieved (850 micro-meter mesh) and sent to the University of Florida Soil Testing Laboratory for chemical analysis of P, Ca, and K.

The elevations were plotted as a function of horizontal distance, and the positions of rises and depressions noted. Chemical, organic matter, and moisture data were selected for the high and the low points and compared for the elevations or depressions, at both depths. Different groupings of data as to elevations or depressions were made, based on the elevation plot. These groups of data were compared for differences. The largest mound was selected and data plotted as a function of distance from the center. Quadratic equations (eq. 3) were used to fit the data. A standard t-test was used for comparisons.

On 28 April 1978 an experiment was conducted on a Lakeland series soil near Keuka Lake, Florida. This series is characterized by deep sand, 2 m or more in depth. A description of this series may be found in Carlise and Moritz (1978). One site was on a freshly cultivated plot and the other a native, uncultivated site. No moisture had fallen on either site for 22 days. A sprinkler was set up and 3.8 cm water was applied to the cultivated site and 2.1 cm to the native site at a rate of 0.8 cm per hour. Small ridges and mounds, 10 cm or less in height were sectioned and visual observations noted. Depth of water penetration was noted on the top of these mounds and in the intervening depressions.

On 3 and 4 May 1978 a total of 9 cm of rain fell on the native site. Mounds 5 cm or less (33 locations) and also level areas (34 locations) were sectioned and the presence or absence of dry soil spots noted. The general slope of this area was 1.0%. A site with a steeper slope was selected (3 -4%) and level areas sectioned and presence or absence of dry soil spots noted (11 locations).

Results

Figure 6.1. is a plot of the transect showing elevations and distance. Two groups of elevations are noted: A large one with an average elevation of 7.5 cm and numerous smaller elevations with an average height of 1 cm or less.

The large mound showed higher contents of moisture, P, and Ca in the depression than in the higher portion of the mound ($P < 0.001$), for the surface 10 cm of soil. Potassium and organic matter did not show a difference between elevations at the $P < 0.05$ level. Organic matter was higher in the depressions ($P < 0.1$) but K showed no difference. At the deeper soil level only moisture showed a difference ($P < 0.01$) with the depressions having the higher value. There were 11 degrees of freedom for the above comparisons. No differences were noted at the $P < 0.1$ level for any of the smaller elevations.

Linear equations (eq. 1) relating the different components to soil moisture in the top 10 cm (13 sample points) gave r^2 values of 0.67 for P and Ca, 0.14 for organic matter, and 0.02 for K. Fitting the data (top 10 cm of soil) to distance from the center of the large mound with a quadratic equation gave r^2 values of 0.68, 0.63, 0.52, 0.50, and 0.04 for moisture, Ca, P, organic matter, and K, respectively. There were 22 sample locations used for these calculations. These data for moisture, Ca, and P were plotted and are presented in Figure 6.2. No relationship was in evidence in the plant communities growing on the mound and adjacent depressions. Sample size is believed to be the major reason.

The data gathered in the second portion of this study on the Lakeland soil are qualitative rather than quantitative in nature. Sectioning the small mounds (1 to 10 cm in height) revealed that the depth of water penetration was about 0.4 to 0.7 cm on top of the mounds and to depths of 10 cm or greater

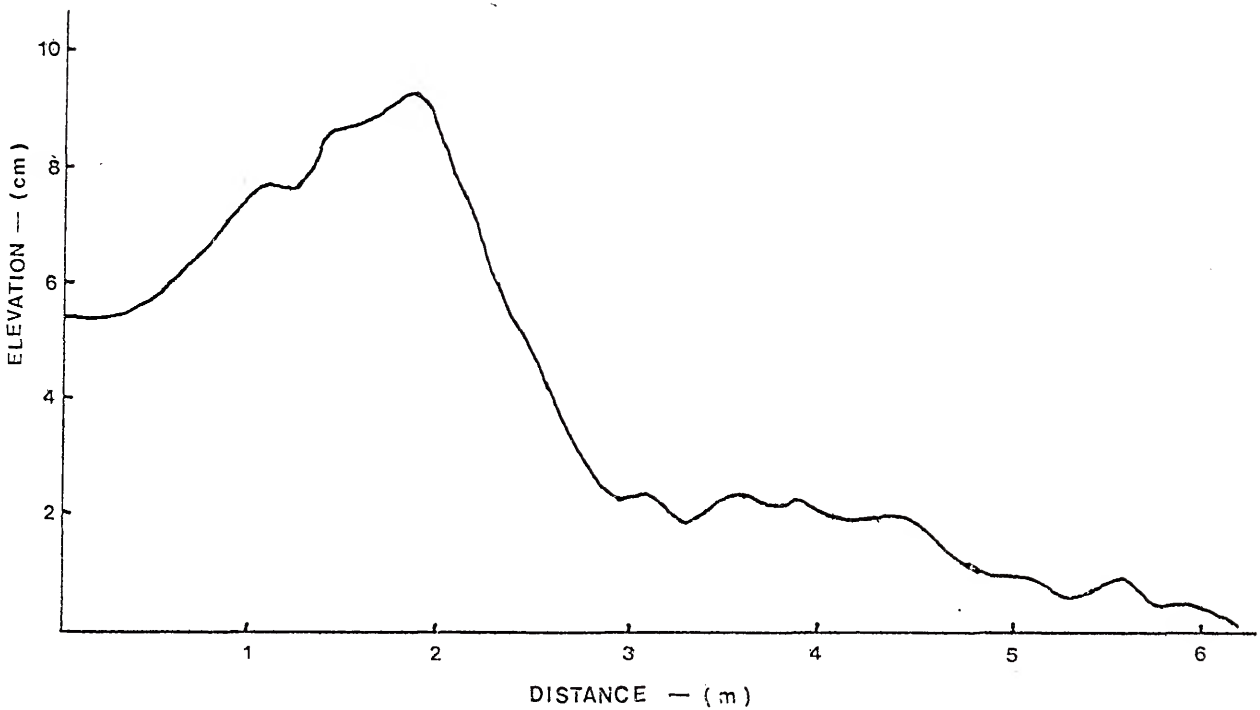

Figure 6.1. Contour of transect of micro-relief study area.

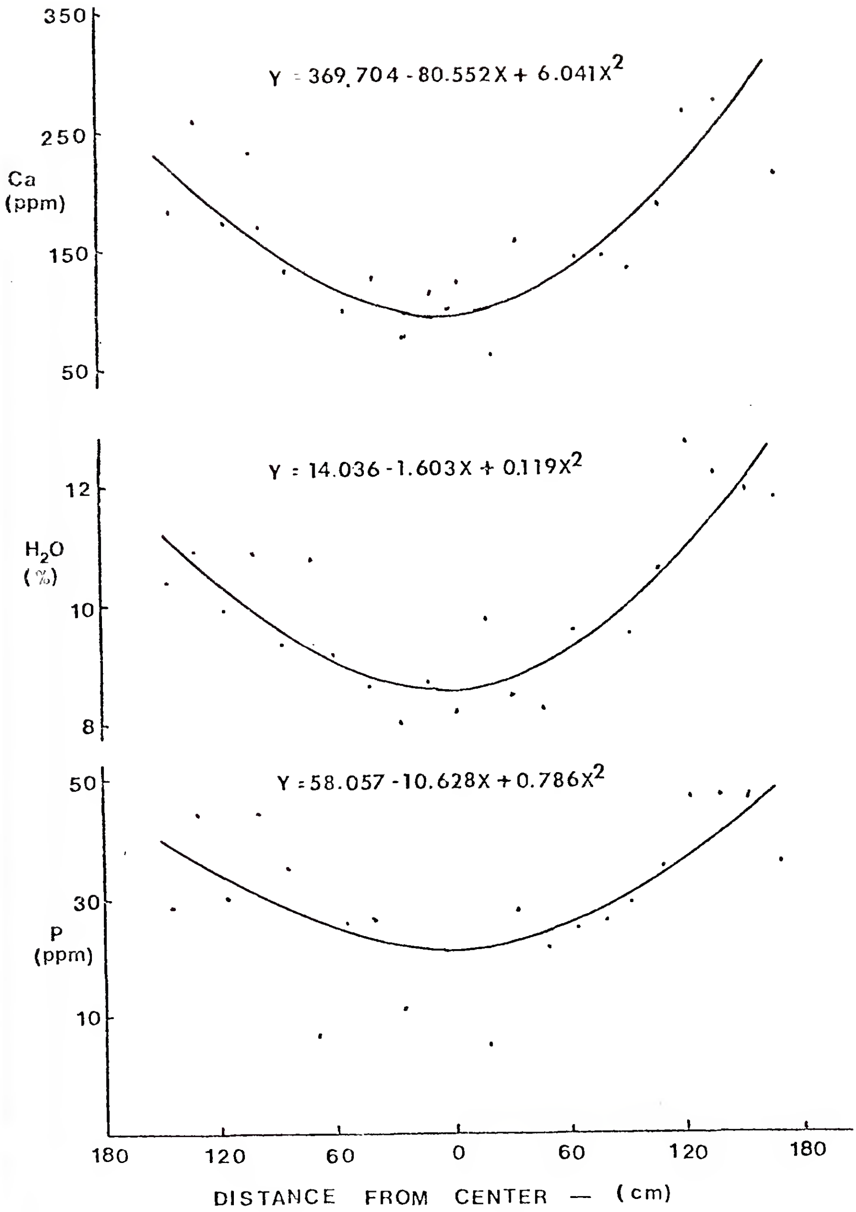

Figure 6.2. Amounts of Ca, P, and water as a function of distance from the center of a small rise in the top 10 cm of soil.

in the adjacent depressions. This same effect was observed in the irrigated native plot. It was also noted that water appeared to follow roots or small sticks that were lodged in the soil. The depth of water penetration around such material was much deeper than in adjacent areas. Leaves and litter laying on the surface also affected water penetration; dry area under leaves were observed extending down to about 1 cm, the actual depth was dependent upon the size of the leaf.

Five hours after the two day intermittent rain ceased, the native area was sampled for dry spots. On the flat area (less than 1% slope) 24% of the sampled (level, no elevation) locations showed dry areas lying 1 cm or less beneath the surface. On the same flat area 76% of the mounds (1 to 5 cm elevation) had one or more dry areas. On the steeper slope (3 - 4%), sampling was confined to flat areas with 36% of these locations having dry areas. No surface obstructions were present on any of the above sample locations.

Discussion and Conclusions

One robin does not make a spring. The results of this investigation are offered as providing one mechanism to explain the degree of variation noted throughout the soils portion of this research. The lack of replication places any conclusions in the realm of speculation; considerable more research on the same and different soils would be needed before any reasonable firm conclusions could be drawn. The following discussion is based on the assumption that the results are repeatable.

There is some basis for the above assumption. Sinai and Zaslavsky (1977) studied this effect of lateral flow in Israeli soils that had been wetted. They noted similar effects from visual observation on sand dunes and clay soils. The anisotropic condition of the soil would appear to be the main argument against such a condition existing in a virgin soil.

There is reason to believe that forest soils under a climax vegetation are not uniform. Goodlett (1954) mentions the effects of wind-throw in producing a high degree of variability over a long period of time, to depths of 90 cm. Lutz (1940), studying a soil in Southern New Hampshire noted irregular and discontinuous horizons, with material from upper and lower horizons intimately mixed. Lutz and Griswold (cited by Goodlett, 1954), suggest that all soils which bear, or have in the past, borne forest stands, have been more or less disturbed. This same sentiment is shared by Drury and Nisbet (1973).

Aside from the mixing effects of wind-throw causing an anisotropic condition other factors could contribute to creating this condition in the soil. Animal movement through the soil and the consequent mixing of materials would be one factor. Another, perhaps more important contributor, is the water insoluble fats, oils, waxes, and resins found in plants and plant litter. Plants contain from 5 to 15% by weight of these components (Gray and Biddleston, 1974). Humic acid, composed of flavonoids and aromatic products of lignin decomposition, are also present in soils, as are small particles of chitin. These so-called end products of decomposition tend to accumulate in soils although not indefinitely since there exist populations of soil microbes that appear to be able to degrade almost anything (Satchell, 1974). The components migrate through the soil and generally come to rest in the B2 horizon (Brady, 1974). The fact that many of these substances are water insoluble would tend to inhibit downward moving water. This would be especially true in areas that had non-uniform deposits of litter. Such areas might exhibit a hydrophobic effect, thus shunting downward moving water into horizontal paths or lateral flow.

Observation on the Lakeland soil tends to substantiate the premise set forth by Sinai and Zaslavsky (1977) as lateral flow existing in a natural state. The observation at the BRU gives some insight as to the effects of this lateral

water movement and helps to explain the high variability noted for the various nutrients taken from samples obtained a short distance from one another.

In sands it might be expected that nutrient particulate movement would also occur, as well as by solution. The volume of water flowing in the top surface layer would be considerably larger, due to the reduced channel size, than would be expected if water movement were uniform. This increased flow would move particulate material and deposit it, much as a stream does, when flow is reduced upon reaching a level fetch, thus building up concentrations of nutrients in the depressions at the expense of the higher elevations.

Two aspects of soil variability need to be mentioned. The effects of different methods of handling can cause differences in chemical analysis (Chapter 5). However, all samples taken in this study were handled the same. The other aspect is attempting to define a large surface area on the basis of 5 g of material. The problem of obtaining an accurate picture of the soil component for fertilizer recommendations has been resolved by recommending that 15 to 25 cores should be taken from a similar soil and composited (Smith, 1977; Sanchez, 1976). Soil variability does not have the same meaning in a natural ecosystem, where the nutrient quality of the particular micro-site may be quite significant to a seed that happens to fall on that site. Since each species has a center of nutrient preference for maximum seedling survival (Whittaker, 1975), species composition may be intimately related to soil variability.

The above assumptions, if proved correct, would help to explain the variations that exist in a natural ecosystem. Research should be directed in verifying the existence of lateral flow in a natural setting, and what effects, if any, these dryer sites have on community structure.

CHAPTER 7

IN VITRO DIGESTIBILITIES OF RANGE FORAGES

Introduction

In vitro digestibility determinations of range species found in North Central Florida are virtually non-existent. Some studies were made by Young (1977) on ten species. *In vitro* digestibilities and chemical constituents were presented for the months of July, August, and September. Other investigators working in different states have determined digestibilities of species that are found in Florida (e.g. Lewis et al., 1975, in Georgia; Campbell et al., 1954, in Louisiana; Voigt, 1958, in Texas). This work was initiated to provide an information base for comparison in future investigations and also to provide nutritional data which will be of use to the various rangeland users.

In vivo digestibility trials have been the mainstay of evaluating forages for animal consumption for many years (Schneider and Flatt, 1975). However, feeding trials are expensive to operate in terms of time, money, and utilization of facilities. Feeding trials also have some additional limitations when used for range forage evaluation, primarily due to the large numbers of species that may be selected by the animal when grazing a rangeland, and the inherent difficulty of duplicating day-to-day diets. Different indicator methods have been developed for estimation of the *in vivo* parameters under grazing conditions. Harris et al. (1967) outlines proceduress for use of *in vitro* estimates combined with estimates of fecal output. However, this method does have some inherent problems (Short, 1970).

The use of two-stage *in vitro* technique developed by Tilley and Terry (1963), for the routine screening of forages is a method that is increasingly being used, when large numbers of different forages are to be analyzed (Moore and Mott, 1973; Pearson, 1970; Milchunas, 1977). The two-stage *in vitro* technique is considered to be more accurate in predicting *in vivo* digestibility than the Weende system (Henneberg, 1859), or other proximate methods such as proposed by Crampton and Maynard (1938), or the comprehensive system of feed analysis developed by Van Soest (1967), (Minson et al., 1976; Moore and Mott, 1973; Moore, 1973). This is not too surprising since bacteria are sensitive to undetermined factors influencing the extent of digestion (Van Soest, 1967). Barnes (1973), in a comprehensive review of literature of the different laboratory methods of predicting digestibility favors the two-stage method as giving the highest correlation to *in vivo* results than either the one-stage, or other laboratory methods.

The primary purpose of this study was to gather preliminary data on various range species as an aid in evaluating ranges and rangeland potential. To this end, only *in vitro* digestibilities and mineral analysis (P, Ca, and K), (Chapter 8) were determined on various species at different seasons.

Because of differences in morphological and anatomical characteristics between range species and the type of forages (grasses and legumes) that are usually associated with *in vitro* analysis, some earlier experiments were duplicated, in theory, if not in actual methodology. Pearson (1967) studied the effects of using inoculums from animals grazing range species to animals grazing pasture species and noted no overall differences. However, Nelson et al. (1972) found highly significant differences in digestibilities of the same forages when different inoculums from different diets were used. It was felt by this investigator that the rumen microflora of an animal grazing

a native range should be different than that of an animal fed a uniform diet, and consequently, the digestibilities of species (compared with the different inoculums) would be different. This hypothesis was tested. Pearson (1967) also investigated the effect of the different components of the in vitro technique on a range species (chaparral) in Arizona. A similar investigation was also conducted on two different range species found in Florida. Effects of length of fermentation time have been investigated by Tilley et al. (1960) and Barnes (1966); three Florida species were used for this aspect of the study. Fineness of grind has been shown to increase in vitro digestibilities if ground very fine (Minson and Milford, 1967), while having the opposite effect in in vivo studies (Moore, 1964). This effect was not investigated and the recommendations of Van Dyne (1962), grinding with a 1 mm mesh screen, were followed.

Other methods of in vitro techniques for predicting forage quality, utilizing the different animals than ruminants, have been attempted with varying degrees of success. Asay et al. (1975) used adult crickets on genotypes of Festuca arundinaceae and noted no correlation. However, Pfander et al. (1964), using cricket nymphs, obtained the same ranking of forages as when fed to sheep. Caswell and Reed (1976) used ten species of grasshoppers to test the unavailability of nutrients in C_4 plants, no ranking of forages was presented.

It has been well documented that plants with the C_4 type pathways (Hatch-Slack cycle) are generally less nutritious for herbivores than C_3 type (Calvin-Bensen cycle) plants (Caswell et al., 1973). It has also been documented that tropical forages are, in general, less digestible than temperate forages (Moore and Mott, 1973; Ludlow, 1976). Since numerous range species found in Florida are known or suspected of having the C_4 pathway, primarily in the family Gramineae, a discussion of this aspect is presented in the conclusion.

Materials and Methods

Samples were collected from each pasture just prior to cattle entry throughout the course of the study. A complete description of sampling methods are given in Chapter 3.2.; dates of collections are found in Appendix A, Table A.1. Each sample represented a total clip of each specie found in the quadrat with standing dead material included. Samples were then dried at 70°C for three days and stored at room temperature in paper sacks. Pearson (1970) reported no changes in sample characteristics dried at 40, 100°C, or freeze drying temperatures. The 70°C temperature was selected since there have been some reports of undesirable changes occurring at higher drying temperatures (Van Soest, 1965; Urness et al., 1977).

The *in vitro* analysis was begun in September 1977 and concluded in February 1978. Samples were ground (1 mm mesh screen) and stored in plastic (Whirl-Pac) bags at room temperature until needed (large woody material was removed prior to grinding). The two-stage *in vitro* analysis was conducted at the University of Florida Range Laboratory.

To determine the rates of digestion occurring in the *in vitro* process, ten uniform subsamples of four species (*Smilax auriculata*, *Centella asiatica*, *Trilisa paniculata* and *Andropogon capillipes*) were prepared and *in vitro* analysis initiated. These species were selected as representing a wide range of plant types found at the BRU. Two samples of each species were removed after 5, 24, 48, 72, and 96 hours (completion of the run). Upon removal from the *in vitro* sequence the samples were dried, ashed, and digestibilities calculated. A quadratic equation (eq. 3) was used to fit the data as a function of time.

Investigation as to the effects of the various components that make up the two-stage *in vitro* technique were conducted using two species (*Smilax*

auriculata and Trilisa paniculata). A solution containing rumen fluid, artificial saliva, and a solution of HCl and pepsin (40 ml of distilled water was added to insure proper wetting of the samples) were prepared. These solutions were added to six uniform subsamples of each specie then placed in the incubator. Two samples of each species were removed at 6, 24, and 48 hours. Effects of saliva alone were determined by adding 40 ml of artificial saliva to six uniform subsamples of the above two species, placed in the incubator, and two samples of each specie removed at 5, 10, and 15 minute intervals. Effects of water alone were determined as for the saliva test, except that S. auriculata samples were removed at 10, 20, and 50 minute intervals and T. paniculata samples removed at 5, 10, and 15 minute intervals.

To test the possible effects of different donor animals on digestibilities, rumen fluid was collected from the steer maintained at the Animal Nutrition Laboratory and from a steer that had been grazing the study site three weeks prior to the collection date (20 February 1978). In vitro analysis was conducted simultaneously with both inoculums on 22 species selected for this comparison. These species represented a mixture of collecting dates and pastures. Each species was run in duplicate for both inoculums. Foliar content of P, Ca, K, and protein were also determined for these samples.

The test for differences due to treatment effects (length of rest) was conducted by collecting samples of 12 different species from all 16 pastures in September 1977. These species were selected since they were common to all pastures in the study. The species selected were: S. auriculata, Galactia spp., Tephrosia spp., Q. pumila, V. myrsinities, C. nictitans, C. americana, Desmodium spp., S. repens, A. stricta, H. graminifolia and T. paniculata. With the exception of A. stricta, five plants, randomly selected from each pasture, were composited for each specie. The samples of A. stricta were not

composited; each plant was analyzed separately. A healthy vigorous condition was the main criterion for selection of all species with standing dead material included.

Seasonal digestibilities of different species were computed by taking the average of all samples collected in that season (e.g. Winter, December 21 to March 21). All samples from all pastures were used for this determination, regardless of treatment. Irrespective of the number of plants that comprised the composited samples, all samples were given equal weight.

Grasses that occurred on the study site were divided, where possible, into warm or cool season, depending on the time of flowering and/or amount of growth that occurred in each season. References used for this classification were: Yarlett (1965); White (1973); Leithead et al. (1971); Gould (1968); Hitchcock (1951); and Grelen and Duvall (1966). Division of the grasses into metabolic pathways (C_3 or C_4) were made according to determination by Downton (1975), Moore (1977), and Teeri and Stowe (1976), or by a comparison of growth habits and related species within the same genera.

Classification of non-grass species into normally associated habitat types (wet, moist, or dry) were made from reference to Halls (1977); Duncan and Foote (1975); Oefinger and Halls (1974); and Halls (1977). Ranking herbivore preference with respect to livestock (cattle), deer (Odocolleus virginianus) and insects is meant to serve only as a guide as to what plant species have been found in the respective herbivore diets. This is not to imply that other consumer species (e.g. birds, other wildlife, and livestock, etc.) do not utilize these plants. This ranking reflects the three consumer groups that were of concern in this study. References used were Halls and Ripley (1961); Harlow and Jones (1965); Schopmeyer (1974); Harlow and Hooper (1971); White (1973); Leithead et al. (1971); and Yarlett (1965).

Results

Of the four species that were used to determine rates of digestion during the two-stage in vitro process, three (Smilax auriculata, Centella asiatica, and Trilisa paniculata) were over 96% complete at the end of 48 hours. Andropogon capillipes was 88% complete (Figure 7.1.). A fit of the data to a quadratic equation (eq. 3) gave coefficients of determinations (r^2) of 0.95 or higher for each of the four species.

The effects of the different components of the two-stage in vitro technique are presented in Table 7.1. for Smilax auriculata and Trilisa paniculata. With the results obtained at the end of a standard in vitro run (96 hr), as a comparison, percent of the expected digestibility were calculated for various lengths of time that the samples were in the respective mediums. Both species displayed a large amount of water soluble contents (74% for Smilax and 39% for Trilisa), that were removed in a very short period of time (5 to 7 minutes). The use of siliva did not appreciably change the percentages noted for water alone. The microbial portion of the process (saliva plus rumen fluid) extracted a higher percentage of the expected value than did the acid-pepsin portion at the end of 48 hours of digestion.

The effects of using inoculums from different donor animals was quite pronounced ($P < 0.01$) with the digestibilities of the range steer only 69.2% of the laboratory steer (Table 7.2.). Crude protein (6.25 times the percent of nitrogen), phosphorus, calcium, and potassium were also determined for this group of samples (Table 7.3.). Linear regressions (eq. 1) were calculated, using different chemical data, in an attempt to predict digestibilities resulted in r^2 values of 0.24 or lower. When a multiple linear regression (eq. 2) with two variables (Ca and K), was used the r^2 rose to 0.44. These were not different at the $P < 0.05$ level.

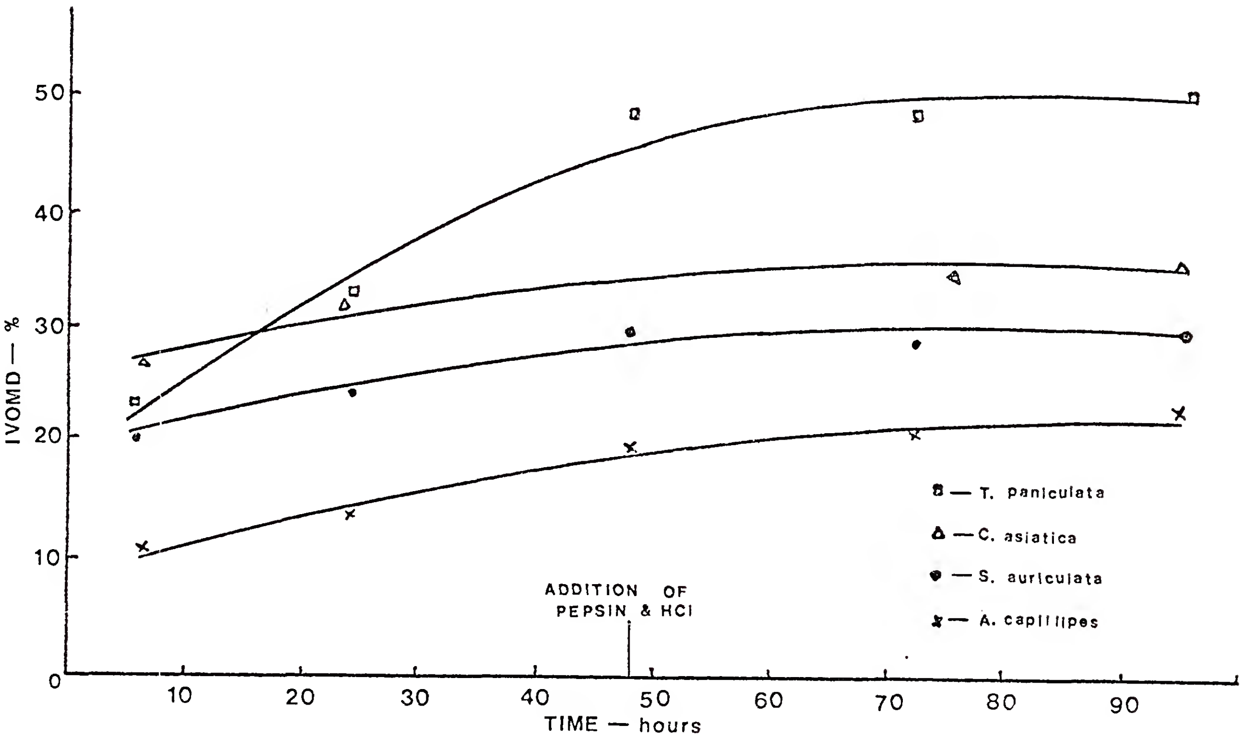

Figure 7.1. *In vitro* digestibilities of four range plants as a function of time of removal from *in vitro* process.

Table 7.1. Effects of different components of the two-stage *in vitro* technique on digestibilities of *Smilax auriculata* and *Trilisa paniculata*.

	Dig. (%)	Time	% of[1] base	Dig. (%)	Time	% of[1] base	Dig. (%)	Time	% of[1] base
Saliva and Rumen Fluid									
S. auriculata	21.3	7.25 (hr)	69.6	24.6	24.0 (hr)	80.4	30.1	48.0 (hr)	98.4
T. paniculata	24.1	7.00 (hr)	47.3	32.7	24.0 (hr)	64.2	48.9	48.0 (hr)	96.1
40 ml water, pepsin and HCl									
S. auriculata	25.7	6.00 (hr)	84.0	25.9	24.0 (hr)	84.6	27.0	48.0 (hr)	88.2
T. paniculata	25.2	7.50 (hr)	49.5	29.8	24.0 (hr)	58.5	32.2	48.0 (hr)	63.3
40 ml saliva									
S. auriculata	22.7	5 (min)	74.2	24.5	10 (min)	80.1	24.2	15 (min)	79.1
T. paniculata	20.0	7 (min)	39.3	21.2	11 (min)	41.7	21.7	17 (min)	42.6
40 ml water									
S. auriculata	22.8	10 (min)	74.5	22.3	20 (min)	72.9	22.0	50 (min)	71.9
T. paniculata	20.0	6 (min)	39.3	20.6	10 (min)	40.5	21.5	17 (min)	42.2

1. Base values were normal length run (96 hr.), two stage digestibilities of 30.6% for *S. auriculata* and 50.9% for *T. paniculata*.

Table 7.2. Effect of innoculum from steer used as standard and range steer on <u>in vitro</u> digestibilities of twenty-one range species.

Specie [2]	Mo. & Yr. Collected	Dig. (%) Standard Steer [1]	Dig. (%) Range Steer [1]
Andropogon callipes	Jan.1978	22.6	13.8
Andropogon virginicus	Jun.1977	27.0	14.7
Aristida stricta	Sep.1977	15.1	10.0
Cassia nictitans	Aug.1977	19.9	16.6
Centella asiatica	Aug.1977	37.3	31.3
Heterothecia graminifolia	Jun.1977	28.3	20.2
Galactia spp.	Jun.1977	27.4	21.4
Ilex glabra	Jun.1977	39.3	34.6
Lyonia lucida	Sep.1977	28.4	25.0
Panicum anceps	Sep.1976	51.2	24.1
Paspalum urvillei	Jan.1978	49.3	31.0
Quercus incana	Jul.1977	19.8	15.6
Quercus pumila	Sep.1977	19.2	11.6
Schizachyrium stolonifer	Aug.1976	22.3	10.9
Serenoa repens	Sep.1977	13.4	11.8
Smilax auriculata	Jul.1976	30.3	22.6
Sorgastrum nutans	Jul.1976	34.8	14.0
Sporobolus curtissii	Sep. 1977	15.5	9.9
Sporobolus juncea	Sep. 1977	12.4	10.2
Tephrosia spp.	Sep.1977	33.8	24.4
Trilisa paniculata	Sep.1977	48.7	36.2
Vaccinium myrsinites	Jul.1977	32.4	26.3
Average		28.6	19.8

1. Collection date, February 20, 1978.
2. All species italicized.

Table 7.3. Nutrient content of forages used for comparison of different innoculums.

Specie[1]	Protein (%)	P (ppm)	Ca (ppm)	K (ppm)
Andropogon callipes	5.8	975	1380	4180
Andropogon virginicus	4.3	840	3250	6600
Aristida stricta	3.3	370	1820	1820
Cassia nictitans	12.7	730	7030	8150
Centella asiatica	11.5	1500	13210	8116
Heterothecia graminifolia	6.1	980	10030	7190
Galactia spp.	13.9	1130	11220	6090
Ilex glabra	3.1	580	7040	1560
Lyonia lucida	3.7	300	14790	1970
Panicum anceps	6.1	870	5640	11980
Paspalum urvillei	11.4	1140	2630	23270
Quercus incana	7.8	660	8090	5140
Quercus pumila	7.1	650	7640	2880
Schizachyrium stolonifer	4.2	523	1260	1770
Serenoa repens	5.7	550	1390	11750
Smilax auriculata	6.0	550	7230	2560
Sorgastrum nutans	3.4	960	2460	4950
Sporobolus curtissii	3.6	1750	2440	1760
Sporobolus juncea	3.2	460	1830	1220
Tephrosia spp.	11.7	1110	13640	3810
Trilisa paniculata	6.6	670	13470	6340
Vaccinium myrsinites	4.0	390	10350	2660
Average	6.6	810	6720	5720

Note: These data are supplemental to data in Table 7.2.

1. All species italicized.

Of the 12 species that were used to test for effects of length of rest on in vitro digestibility, only four had significant F values (S. repens, A. stricta, Q. pumila and T. paniculata). When the averages were ranked three of the species showed a higher digestibility associated with complete rest, compared to the other treatments. However, upon separation of the means only Q. pumila demonstrated a difference between no grazing and the other treatments. Averages for each of the 12 species were summed according to treatment, all replications were included. A linear regression equation was fitted to the treatment averages, the r^2 was 0.08; when only replications I and II were used, the r^2 was 0.45 (not different at $P < 0.05$ level).

Seasonal variations in digestibilities were noted for most of the species observed where complete seasonal collections were available (Table 7.4.). Quercus incana showed little difference in digestibility from season to season. Quercus pumila, Ctenium aromaticum, and Aristida stricta showed slight changes. Centrosema spp. showed a large change, however the spring collection was only represented by two samples. Averages, standard deviations, and coefficients of variation for all species that were analyzed over the collecting period (six seasons) are presented in Appendix E, Table E.1.).

Data gathered from the literature on scientific and common names, habitat type, principal herbivore (cattle, deer or insects) for some of the trees, shrubs and forbs are presented in Appendix A, Table A.2. and A.3. The grasses (Appendix A, Table A.3.) have, in addition to the above, a compilation of probable metabolic pathway (C_3 and C_4) and considerations as to whether warm or cool season species. An interesting aspect of this listing of the grasses as to probable metabolic pathway is the large number (20) of C_4 type species found at the site compared to the single C_3 specie.

Discussion and Conclusions

The rates of digestion for the four species (Figure 7.1.) compared well with data from Pearson (1970). The majority of the digestion occurred during the microbial portion of the process. Two of the grasses in the above study by Pearson were C_4 species and both of these had lower digestibilities than the other C_3 species that were tested. The rates of digestion were also lower, being 82 and 87% complete at the end of the microbial portion (48 hours). This compares to the 88% obtained in this study for Andropogon capillipes (a suspected C_4) for the same time period.

Gumma (1977), working with an esophageal-fistulated animal, comparing diet selections obtained by the microscopic point analysis and bit count observations, noted a fairly large discrepancy in S. auriculata. The microscopic point analysis being 67% less than the bite count observations. With S. auriculata being 74% water soluble (Table 7.1.), this difference becomes a reasonable extension of the process of biting, masticating, and the length of time the material remained in the collection bag before being dried with the water soluble portion adhering to the bag.

The use of inoculums from different donor animals resulted in the laboratory animal having considerably higher digestibilities than the range steer ($P < 0.001$). It was expected that there would be a difference between the two animals since it was felt that the rumen microflora of the range steer would be better adapted to digesting range forage than the microflora of the laboratory steer. However, the laboratory animal had the higher digestibility in the comparison. The major reason for this discrepancy appears to lie with the physical condition of the range steer. Throughout the study he had consistently lost weight whenever placed on the study site. A companion cow that was with him during the three weeks prior to the collection date was in excellent condition. It would have been of interest to have been able to compare rumen fluid from

Table 7.4. Seasonal variations in digestibilities of various range plants, in percent.

Species[1]	Summer 1976	Fall 1976	Winter 1977	Spring 1977	Total # of Samples
Andropogon virginicus	15.4	24.5	21.1	26.5	15
Aristida stricta	17.6	15.2	13.3	15.5	102
Callicarpa americana (berries)	39.4	36.2	-	-	3
Cassia nictitans	19.3	22.6	-	28.2	31
Centrosema spp.	39.0	36.9	-	15.7	15
Ctenium aromaticum	25.1	23.5	21.6	24.5	63
Eragrostis spectabilis	38.7	30.9	24.7	31.5	20
Galactia spp.	34.1	27.1	-	41.2	43
Heterotheca graminifolia	36.0	34.2	40.7	41.2	95
Panicum anceps	51.1	38.1	39.1	54.7	19
Paspalum notatum	48.6	44.2	36.9	57.5	9
Quercus incana	22.9	22.3	22.8	21.9	72
Quercus pumila	20.9	19.1	17.6	18.4	22
Schizachyrium stolonifer	31.6	30.1	27.3	34.2	75
Serenoa repens	18.3	16.6	23.6	22.0	30
Smilax auriculata	30.2	34.4	27.9	33.2	23
Sorghastrum nutans	34.6	19.5	17.7	26.9	15
Sporobolus curtissii	26.4	22.8	21.5	18.8	32
Tephrosia spp.	32.1	35.8	-	40.9	19
Vaccinium myrsinites	33.9	31.7	22.6	39.0	27

1. All species italicized.

this animal to that of the laboratory steer. Unfortunately, the steer was the only fistulated animal available.

Health is an important criterion when using inoculum from an animal (Barnes, 1973). The range steer was not diseased, but was undernourished and had lost close to 45 Kg (100 lbs) prior to collection of the inoculum. Pearson (1970) suggests using inoculum from animals grazing the forage to be tested as providing the most reliable information.

Another possible reason for the poor performance of the range steer may be a result of the low P content of the forages and the consequent low P level in the diet. This low dietary P intake level might result in the rumen bacteria not having sufficient P for normal growth and development. This in turn would result in lower efficiencies in the digestion of the forages. Natural selection pressures would also be operating on the rumen bacteria, favoring those capable of functioning at low P levels, which in all probability would not be the ones capable of rapid assimilation of foodstuffs. Even though P is added to the inoculum, via the artificial saliva, the amount may not be sufficient, or if sufficient the composition of the resident rumen bacteria might be such as to preclude efficient digestion in the normal duration of an *in vitro* run.

Due to the poor condition of the range steer, no conclusion can be drawn as to effects of using inoculum from different animals in *in vitro* digestibilities of Florida range species. More research is needed to delineate this suspected difference.

It is of interest that the use of two variables (Ca and K) used in predicting digestibility in a multiple regression equation (eq. 2) resulted in a coefficient of determination of 0.44 compared to a single regression equation (eq. 1) where r^2 was 0.15 for Ca and 0.24 for K. Van Soest (1967), when discussing the use of single chemical constituents (i.e. crude fiber, acid

detergent extract, etc.) to predict in vivo digestibility, cautions against the use of just one constituent and proposes the use of a summative equation to predict digestibilities. The use of elemental chemicals in attempting to predict digestibility apparently has not been seriously considered.

Calcium has some interesting properties in its association with livestock and livestock feeds. It has long been known that oxalic acids is one of the most abundant and strongest acids found in plants (Gallaher, 1975). Schimper (cited by Gallaher, 1975) suggested that one of the principal functions of Ca is to precipitate oxalic acid as Ca-oxalate, thus preventing possible injurious effects to the plant. A suggested treatment from oxalate poisoning in animals is the administration of Ca (Merck, 1967). Calcium, when fed to cattle (kiln dust in feed rations), causes a significant increase in gain in weight (Maugh, 1978). Whether the effects noted in the feeding trials are due to the buffering action that takes place in the rumen or interactive effects with other feed components, the mechanism is not understood at this time. The use of CaCl in the in vitro buffer solution may tend to mask the effect of Ca that is noted in animal research. More effort needs to be directed alont this line of research.

The failure to obtain a consistent meaningful difference in in vitro digestibility as a function of length of rest for selected range species does not necessarily imply that no differences exist, only that the experimental sample size was not sufficiently large enough to detect those differences (Chew, 1978). All of the 12 species that were selected had been grazed to some extent during the course of the experiment. Consequently, they could expect to be under some grazing stress, particularly in the two-month rest treatment. Different species react to grazing pressures in different ways, and there is no reason to assume that the response of all species would be similar. In this respect it would have been desirable if one or more species

had been selected that were generally considered unpalatable (pines, large oaks), and these tested for differences in _in vitro_ digestibility, as was done for the chemical analysis. Another factor that is probably confounding the results is the difference in soil characteristics (Chapter 4). When all species were summed for each treatment and all replications used, low r^2 values were obtained. This low value compared to the higher r^2 value when only replication I and II were used, points up to a possible soil-chemical; plant-digestibility interaction. As mentioned in Chapter 4, replications I and II are the most similar, soilwise, of the four.

In the computation of seasonal digestibilities of the various species no multiple comparison procedures were used to test for differences in seasons. Multiple comparisons tests are almost never appropriate for experiments in which the treatments are graded levels of a quantitative variable (Peterson, (1977). Seasons seemingly fall into this category, particularly so since the samples were collected at different times in each season, depending upon dates of collection (Appendix A, Table A.1.).

For pasture grasses _in vitro_ digestibilities have been shown to decline with increasing maturity (Moore, 1973; Abrams et al., 1978). This same effect was assumed to occur in range species, however _Quercus incana_ appeared to remain fairly constant over the year. Since this is a deciduous species more variation would be expected as a result of regrowth affects. The relatively low values of the coefficient of variation and the reasonable large number of samples involved would seem to indicate that this trend is real, and should be investigated further.

The large ratio of C_4 to C_3 (20 to 1) for the grasses found at the study site has some profound implications for grazing management in Florida. Of 75 species of grasses listed by Yarlett (1965), 21 species have the C_4 pathway according to Downton (1975). An additional 42 species are strongly suspect

based on Gould's (1968) classification of grasses into tribes (Teeri and Stowe, 1976). Thus some 84% of the grasses listed as important for range conservation in Florida either have a C_4 pathway or are strongly suspected of having it.

There are three major classifications of plants based upon their method of fixing carbon dioxide; the Calvin-Bensen RuDP carboxylation (or C_3), the dicarboxylic (C_4), and the Crassulacean acid metabolism (CAM) (Moore, 1967). The CAM cycle apparently has been evolved primarily as a survival mechanism, a method of "hanging-on" until conditions get better. The C_4 plants are generally considered to be less efficient from an energy standpoint than C_3 plants. However, when the cost of photorespiration are added for the C_3 plants the two pathways are about the same (Black, 1973). The C_3 and the C_4 plants are of concern here because of the numerous differences, biochemically and morphologically. Of primary interest is the seemingly lower forage quality of the C_4 species compared to C_3 species. The C_4 pathway has been found in at least 13 plant families, with Graminacea having the largest portion. In addition, different species within the same genus exhibit different pathways (e.g. subgenus Dicanthelium is primarily C_3 and Eupanicum primarily C_4) (Downton, 1975).

It has been known for some time that tropical grasses are generally lower quality than comparable temperate grasses (Patterson, 1935). Whyte (1962) argues that native tropical grasslands have neither the potential quality nor the yield required to achieve improved animal performance. This low quality of tropical grasses is a major problem, however other factors (environment, nutrition, management, etc.) must be considered (Moore and Mott, 1973). In simultaneous comparisons of two tropical species (Panicum and Setaria) and two temperate cultivars of Lolium perenne Wilson and Ford (1971) noted an increase in cell wall constituents and a decrease in *in vitro* dry matter digestion as day and night temperatures increased. Fertilization studies (nitrogen and phosphorus) by Wilson and Haydock (1971), on a wide variety of temperate and

tropical grasses indicated a general increase in *in vitro* dry matter digestibility as levels of fertilization increased. Other authors have noted similar increases of digestibility with increased levels of fertilization, especially nitrogen (Ludlow, 1976; Rogler and Lorenz, 1973; Salih and Burzlaff, 1977).

Silica has also been demonstrated to affect forage quality. Van Soest and Jones (1968) reported that an increase of silica content of 1% dry matter decreased dry matter digestibility by three percentage units. Smith et al. (1971) reported an increase of 1% of silica in dry matter decreased digestibility one percentage unit. However, Minson (1971) could find no relationship between silica and OM digestibility. When the species that were used are sorted as to metabolic pathway, the two studies that showed a correlation with silica did so with predominantly C_4 plants. The study by Minson utilized several panicum species which contained both types of pathways. The failure to separate the species as to metabolic pathway might be one reason for the conflicting claims as to effects of silica that are found in the literature. Other factors such as the presence of alkaloids may also reduce *in vitro* digestibility in certain pasture grasses (Bush et al., 1972).

In a literature comparison of the crude protein content of 22 C_3 species to 44 C_4 species, Caswell et al. (1973) noted that the C_3 plants had higher levels than the C_4 (14.5 and 8.7%, respectively). Numerous insect feeding trials have demonstrated the inability of C_4 species to support the numbers of herbivores that C_3 species support (Shade and Wilson, 1967; Kroh and Beaver, as cited by Caswell and Reed, 1976). Caswell and Reed (1976), in a study utilizing 10 species of grasshoppers from different areas of the United States, concluded that nutrient material in the bundle sheathes of C_4 plants was at least partially unavailable to herbivores.

If the hypothesis of Caswell et al. (1973) that herbivores tend to avoid feeding on C_4 plants is correct, then the ramifications go beyond the ecological implications of interspecific competition mentioned by Black (1971). If selective grazing is being directed at C_3 forage species this would imply an eventual replacement by a C_4 species. Evans and Tisdale (1972) reported the invasion and apparent takeover of an Idaho grassland, originally dominated by Agropyron spicatum (C_3), by Aristida longieseta (C_4). They attribute this to the low palatability of A. longiseta and the consequent selective grazing of A. spicatum by cattle, sheep, and mule deer.

The above discussion has centered on the general lower quality of C_4 species and the apparent inability of herbivores to extract nutrients from these plants as being part of a natural biological process. Man, at least in Florida, has also played a role in changing the relative proportion of C_3 to C_4 plants. Rightmire and Hanshaw (1973), studying the carbonate chemistry of the aquifer system in Central Florida (stable carbon isotope analysis method), reported that one hundred years ago this area was predominantly of the C_3 vegetation type. This type of analysis utilizes the known ratio of $^{13}C/^{12}C$ that exist for C_3 ($-25 \pm 5\%$) and C_4 (-5.6 to -18.6%) plants (Smith and Epstein, 1971). The total forage acreage, which includes all pastures (woodland and range pastures, forage type crops, etc.) for Florida is approximately 12.2 million acres (IFAS, 1975). Approximately 3.9 million acres of this is planted in C_4 crops (Johnson, 1974)[4]. Most of this acreage has come into existence through recent agronomic practices within the last 100 years, and in 1974 represented 32% of the total forage acreage. The acreage that is currently in the C_4 plant category is projected to increase 12% by the year 1985 (IFAS, 1975).

4. Johnson, J. T., unpublished data compiled from a survey of County Extension Directors.

Thus, man is a significant contributor to the increase of C_4 plants in Florida. The implications of the change in vegetative types and what meaning this has for the insect and wildlife populations is highly speculative and beyond the scope of this current investigation. The livestock industry is faced with a situation where most of the important range grasses, and virtually all of the improved pasture grasses (except for winter annuals) are of the C_4 type. In effect, this places Florida in a situation that is common to the more tropical areas of the world. Therefore, Florida range management systems should be geared to this tropical situation. Research needs to be directed toward identification of the more palatable and digestible species, with concomitant management techniques for better utilization. Animal selection is also a vital criterion, particularly when native range is to be utilized (Chapter 10). Range management in Florida should look to the tropics for understanding and management criteria for its tropical vegetation and cease to consider itself as an extension of the western range.

CHAPTER 8

CHEMICAL COMPOSITION OF RANGE SPECIES

Introduction

The nutrient quality of the soil is expected to influence the quality of the plants growing upon it (Brady, 1974; Loneragan, 1973), thus the basis for soil testing (Melsted and Peck, 1973). While a great deal is known about the nutrient requirements of agricultural plants, little is known about the requirements of wild plants (Larcher, 1975). Nutrients cycle through ecosystems and on this basis certain general predictions can be made concerning particular aspects of the system. If an element is in a tight circulation pattern (deficient), the amount present in the plant is related to the amount in the soil, and the addition of the nutrient to the soil will increase the productivity of the system (Whitaker, 1970; Loneragan, 1973). This concept has led to the development of the technique of foliar analysis. Again, this technique has been developed to a high degree in various agricultural crops (Smith, 1962; Bates, 1971) and forage crops (Martin and Matocha, 1973). Relating foliar nutrient content to growth or yield is usually accomplished through use of the Mitscherlich-Bray growth function (Melsted and Peck, 1977), with expanded versions of this function to predict nutrient application rates (Malavola and DaCruz, 1971). However, Ovington (1968) has questioned whether a meaningful relationship can be obtained between the total nutrient content of the plants and the measured nutrient content of the soil. Part of the difficulty may be that perennials (trees) may rely more on primary minerals and less on readily extractable nutrients (Voigt, 1958). The relationship of

yield to tissue nutrient content becomes even further confused due to the Steenbjerg effect (C-shaped response curve). This effect explains the erratic responses of plants to the addition of a particular nutrient when grown in an overall nutrient poor site (Bates, 1971). This difficulty in interpretation of the soil test results is still the subject of discussion based on two different concepts: sufficiency levels of available nutrients (SLAN) and basic cation saturation ratios (BCSR) (McLean, 1977).

While little is known about the nutrient requirements of the various range plants that make up the understory of the study site, considerable information is available on plantation pines, particularly *P. elliottii* which is extensively grown in Florida. A rather large body of literature concerning its growth, yields, nutrient requirements, etc. has been developed. The literature on *P. palustris* is not nearly as extensive. However, since the two species are very similar genetically and phenotypically, what generally holds for one is valid for the other, with a few notable exceptions. Mineral cycling is an area where it is felt that the two species behave similarly (Fisher, 1978)[5].

In studies where both foliar and soil analysis have been used to predict growth response to P fertilizer, foliar analysis has generally proved to be the more effective (Pritchett, 1968; Wells et al., 1973). Several studies have been made to determine the critical level of foliar P in pines (Jahromi, 1967; Richards and Bevage, 1972; Ballard, 1974). Generally, if foliar P values are below 0.08% for 30 year old *P. elliottii*, there is over a 90% chance that there will be a growth response to applications of P (Richards and Bevage, 1972). Slightly higher values are given for *P. taeda* (0.13). Those cases where foliar P diagnosis fails can probably be attributed to factors such as other nutrients

5. Fisher, R. F., 1978. Asst. Prof. Forestry, Univ. Fla., Personal communication.

or site characteristics limiting production or differences in sampling procedures (Leaf, 1973).

Movement of P into the foliage from applications of fertilizer can be quite short (one day), depending on rainfall (Mead and Pritchett, 1975). This is due to an extensive root system with many small diameter roots lying in the F horizon (Lyford and Pritchett, 1976). Because of this characteristic and the size of the root system, pines are fairly efficient at picking up nutrients that fall to the forest floor.

Animals may be very effective agents in the recirculation of nutrients in a system (Mott, 1974; Heady, 1975). Mineral supplementation to livestock would be expected to add to the nutrient pool of the site with the animals providing the dispersal mechanisms. The competitive advantage of the overstory, through canopy cover (shading) and litter cast determines the composition of the understory (Halls, 1955). The amount of nutrients in circulation and their turnover rates determine the production capabilities of an ecosystem (Odum, 1969). Stresses introduced from grazing, drought, low soil fertility, climate, and the frequency of occurrence are all reflected in the community structure of the ecosystem. Foliar chemical analysis is one method of measuring the community "health".

Before an intelligent program of livestock or wildlife management can be implemented it is essential to know the quality of forage on the site and not just assume that because it is green it is good. Quality of the diet is more important than quantity (Lay, 1964) and to base carrying capacity solely on the basis of quantity is to generally overestimate (Blair et al., 1977). Foliar chemical analysis is one way to measure forage quality. This aspect is the major thrust of this chapter.

Materials and Methods

In general, all samples that were run by the *in vitro* analysis are also represented by chemical analysis. However, due to accidents or experimental errors in this or the *in vitro* procedure, some samples were lost or destroyed. Chemical determinations were also made for some species that were not analyzed for *in vitro* digestibilities. In addition, some samples were represented by such a small amount of material that only a chemical determination was possible. Consequently, the numbers of samples used for the *in vitro* analysis for a particular species, may or may not be the same as the numbers used for the chemical analysis.

The sampling period represents six consecutive seasons, starting in the summer of 1976 and concluding in the fall of 1977. For ease of presentation samples of the selected species were composited for the season of their collection. Averages, standard deviation, and coefficient of variation were calculated of each species for each of the nutrients monitored.

To test for differences in chemical content due to treatment effects (length of rest) 11 different species were collected from all 16 pastures in September 1977. These species selected occurred in all pastures. Five plants randomly selected from each pasture were composited and analyzed for P, Ca, and K, for each of the 11 species. A healthy vigorous condition was the major criterion for selection of all species; standing dead material was included. The species selected were: *A. auriculata*, *Galactia spp.*, *Tephrosia spp.*, *Q. pumila*, *V. myrsinities*, *C. nictitan*, *C. americana*, *Desmodium spp.*, *Serenoa repens*, *P. palustris*, and *A. stricta*. *A. stricta* samples were not composited, but analyzed separately.

To check the possibility that the 11 species selected did not constitute a representative chemical sampling of the total species present, all samples

that had been collected after the last grazing application were pooled for each pasture. Phosphorus levels were determined for each pasture and an ANOVA analysis conducted to determine treatment effects. This procedure was also used for all samples collected at the beginning of the study, summer and fall of 1976.

The effects of length of rest on the chemical composition of the overstory foliage was tested by collected samples from Pinus palustris and Quercus incana. Collections were made of P. palustris in March and August 1977 and March 1978. Samples were obtained from the top sun needles of the dominant trees and only first flush growth needles were taken. Since the trees were quite tall, a rifle was used to shoot the desired clusters of needles from the tree. A preliminary collection (March 1977) consisted of five samples each from the control and the two-month rest pastures of replication I. Phosphorus was the only nutrient determined. The second collection (August 1977) consisted of five samples of each pasture, all replications and treatments represented. The nutrients analyzed for were P, Ca, K, Mg, Al, and Fe. The third collection (March 1978) consisted of five samples each, of all treatments in replication I; also the control and four-month rest pasture in replication IV. Money precluded a complete analysis at this date. Nutrients determined were P, Ca, and K. An ANOVA analysis was used to test for treatment and replication effects with all four replications and replications I and II only. Five samples each were taken of Q. incana from the top sun leaves in November 1977, from the control, two-month and six-month rest, replication III, and from the two- and six-month rest, replication IV. These were the only pastures where large Q. incana occurred. Statistical analysis of the results were similar to that for P. palustris.

To test for possible relationships between soil chemical content and foliar chemical levels linear regression (eq. 1) were used. The nutrients

compared were P, Ca, and K levels found in the soil (Chapter 4). The chemical content of the soil was compared to the foliar content of P. palustris, Q. incana (trees), the 11 representative forage samples, and the composite forage samples on an element by element comparison.

Results

Compiled data of chemical composition for various species in the different seasons are presented in Appendix E, Tables E.2., E.3., and E.4. for P, Ca, and K, respectively. Species are listed in alphabetically order, with the mean, standard deviation, CV, and the number of samples collected for each season.

The test of the effects of grazing on A. stricta, utilizing samples collected just prior to and after cattle had grazed the area resulted in no difference ($P < 0.1$) between the phosphorus content of the samples before and after being grazed.

Each of the chemicals that were monitored (P, Ca, and K) were averaged by grazing treatment for each species. These averages were then summed and a new composite average computed for each pasture along with the CV (Appendix E, Table E.5.). No meaningful treatment effects (completely random design) were noted for any of the three elements. There was, however, considerable variation in chemical content among species as reflected in the high CV's. An average CV of 46.6, 52.3, and 61.0 was calculated for P, Ca, and K, respectively. With the randomized complete block design for the ANOVA test, block (replication) effects were noted at the $P < 0.1$ level while treatment effects were not different.

Because replications I and II are most similar with respect to all chemical elements except P (Chapter 4) averages of foliar chemical content were made over these pastures and are presented in Tables 8.1., 8.2., and 8.3. for

Table 8.1. Average foliar phosphorus content (ppm) of eleven species in replications I and II.

Species[1]	Months of rest			
	2	4	6	12
Aristida stricta	1030	680	640	650
Smilax auriculata	1450	1670	1250	1061
Galactia spp.	2220	1470	1630	1630
Tephrosia spp.	3580	1670	1820	1310
Desmodium spp.	2770	2510	1560	1700
Cassia nictitans	2570	2360	2580	2050
Quercus pumila	1370	1250	1470	1450
Callicarpa americana	2570	2530	2650	2760
Vaccinium myrsinites	720	610	710	880
Serenoa repens	1200	1120	1150	1090
Pinus palustris	470	410	390	410

1. All species are italicized.

Table 8.2. Average foliar calcium content (ppm) of eleven species in replications I and II.

Species[1]	Months of rest			
	2	4	6	12
Aristida stricta	2732	2110	2020	1770
Smilax auriculata	7820	7220	8650	10070
Galactia spp.	12140	11080	11850	11450
Tephrosia spp.	11690	9590	9890	10550
Desmodium spp.	10900	9600	9420	9120
Cassia nictitans	8960	8620	7750	6970
Quercus pumila	12250	12110	7550	9460
Callicarpa americana	5760	5590	5430	4260
Vaccinium myrsinities	8810	9720	10400	9170
Serenoa repens	2290	1240	1660	1690
Pinus palustris	1090	1090	1220	1080

1. All species are italicized.

Table 8.3. Average foliar potassium content (ppm) of eleven species in replications I and II.

Species[1]	Months of rest			
	2	4	6	12
Aristida stricta	3380	3350	3400	2620
Smilax auriculata	9770	10560	6700	6220
Galactia spp.	10270	10580	9390	9560
Tephrosia spp.	5570	5770	5940	4837
Desmodium spp.	6800	12620	9070	6790
Cassia nictitans	7750	11770	9700	8300
Quercus pumila	3880	4800	4430	3900
Callicarpa americana	15720	18230	16770	13860
Vaccinium myrsinities	3250	2500	2750	2970
Serenoa repens	11360	9430	9900	10950
Pinus palustris	1760	1950	1790	1970

1. All species are italicized.

P, Ca, and K, respectively. The ANOVA analysis resulted in no different block or treatment effects for any of the three nutrients ($P < 0.05$).

Three pastures contained large percentages of both wet and dry sites (Figure 4.2.). They are II-2, III-4, and IV-4. Samples were collected in these pastures representing both wet and dry sites. These samples were compared for phosphorus content by a t-test. No difference ($P < 0.1$) was noted. From the soils map (Figure 4.2.) two pastures were selected, one that lies entirely within the wet area (I-2) and another that lies in the dry site (IV-2). The above pastures contained 59 and 84 foliar samples for the wet and dry sites, respectively. Phosphorus content of the dry site was 1220 ppm and 1590 ppm for the wet site, difference at the $P < 0.001$ level.

Linear regressions (eq. 1) relating foliar to soil chemical content were found to be weakly correlated for Ca and K (r^2 less than 0.2) for all plants and plant groups. The r^2 for P was less than 0.2 for *P. palustris*, 0.41 for *Q. incana*, 0.51 for the average 11 representative samples and 0.63 for the composite of all samples collected for each pasture after the last grazing period. Regression equations derived only from pastures that had the same grazing treatment had r^2 values above 0.5 for both plant groupings (11 species and all samples collected after the last grazing period). The no grazing or complete rest pasture showed high correlation ($r^2 = 0.94$) between soil and foliar levels of P. The coefficients of the equation were 23.6 for the slope and 1304.6 for the intercept.

Foliar P for each pasture was averaged at the beginning (1976) and the end (1977) of the study and are presented in Appendix E, Tables E.6. and E.7., along with standard deviations (s) and CV's. These data were analyzed by a randomized complete block design and tested for differences between treatment menas using ANOVA. The 1976 data showed no treatment effects ($P < 0.1$);

however, the block (replication) effects were different at the $P < 0.005$ level. When only replications I and II were used, there were no differences ($P < 0.1$) for either treatment or replication. The 1977 data (all replications) showed a treatment effect at $P < 0.1$ and a block effect at $P < 0.005$. When only replications I and II were used, there was a treatment effect and no replication effect ($P < 0.1$). When all replications were averaged with respect to treatment, no differences were noted ($P < 0.05$), but there were differences when all treatments were averaged with respect to replication (Table 8.4.).

Relative percent change of foliar P (all species composited) was calculated by taking the difference for each pasture between the summer averages for 1976 and 1977 data, and dividing this by the summer 1976 average (Table 8.5.). Statistical analysis indicated no different F value for either treatment or replication effects, when all replications were used or when replications I and II were used. However, when replications I and II were used (most alike with respect to soil P) there was a treatment effect ($P < 0.025$); replication effects were not different. The relative ranking of foliar P as a function of length of rest, lists the six-month rest highest, followed by the two, four, and no grazing treatments. This same order may be noted in the 1977 data (Table 8.4.).

The same procedure (except that 200 was added to the differences to make them all positive) was used for wiregrass. This was the only species where enough samples were collected to have sufficient data points for both years in all but replication III. The ranking of the means was the same as the above composited data. The means separate out with no difference between twelve and four; four and 2; and two and 6; at the $P < 0.05$ level. The block effects (replication III was missing) were not statistically meaningful (Table 8.6.).

Table 8.4. Mean separation analysis of treatment and replications for foliar P content at beginning and end of experiment.

1976 Data				
Months rest	2	4	6	12
Avg. P for all Rep.	1038a	1042a	999a	1066a
Replication	II	I	IV	III
Avg. P for all trt.	978ab	1058b	829a	1280

1977 Data				
Months rest	2	4	6	12
Avg. P for all Rep.	1256a	1169a	1281a	1138a
Replication	I	II	III	IV
Avg. P for all trt.	1212a	1194a	1395	1042

Note: Numbers followed by same letter are not significant at $P < .05$ level. Data taken from tables E.6. and E.7.

Table 8.5. Relative percent change of foliar P from summer 1976 to summer 1977, composite of all species.

Months rest	Replication I	II	III	IV	$\overline{X}$
2	25.0	13.5	23.8	10.7	20.80
4	8.9	5.4	2.2	46.8	15.80
6	26.8	33.7	16.2	41.8	29.60
12	-0.3	26.8	-1.7	9.8	8.65
$\overline{X}$	15.1	22.4	10.1	27.3	

Table 8.6. Change in foliar P content from summer 1976 to summer 1977 for *A. stricta* (ppm).

Treatment	Replication			
	I	II	IV	$\bar{X}$
2	460	329	243	344
4	195	147	241	194
6	253	696	533	494
12	161	48	26	78

Treatment F = 4.362 Block F = 0.102

Note: 200 was added to make all entries positive.

Phosphorus content for the samples that had been collected after the last grazing period were summed and averaged for each pasture. It was noted that the F value for treatment effects for replication I and II were different at the $P < 0.05$ level while for replications III and IV there were no treatment effects.

The test for treatment and block effects were made using the randomized complete block design. Two groupings (replications I and II) and (all four replications) were tested for both the 11 representative species and for the composite of all samples collected after the last grazing date. In both groupings of samples there were block effects when all replications were used and no treatment effects ($P < 0.05$). When only replications I and II were used, block effects were not different ($P < 0.1$ level). There were treatment effects ($P < 0.05$) for the 11 species and these differences increased ($P < 0.001$) for the composite samples collected after grazing.

Using the average values obtained for the 11 representative species (from replications I and II), linear regression equations were developed for P, Ca, and K as a function of length of rest (Figures 8.1., 8.2., and 8.3., respectively). The r^2 values were 0.896 for phosphorus and 0.943 for calcium. Potassium had a very weak correlation ($r^2 = 0.280$). When all eight values were used for both replications, the r^2 for P was 0.684 and 0.698 for Ca.

Most of the 11 species selected showed an increase in foliar chemical content as the length of rest decreased for each of the three elements (Tables 8.1., 8.2., and 8.3.). In addition, a higher percentage of the species represented showed an increase in the foliar chemical content for all three elements as the length of rest decreased (Table 8.7.).

Samples collected for Pinus palustris during the summer were averaged and CV determined for each pasture for P, Ca, K, Mg, Al, and Fe (Appendix E,

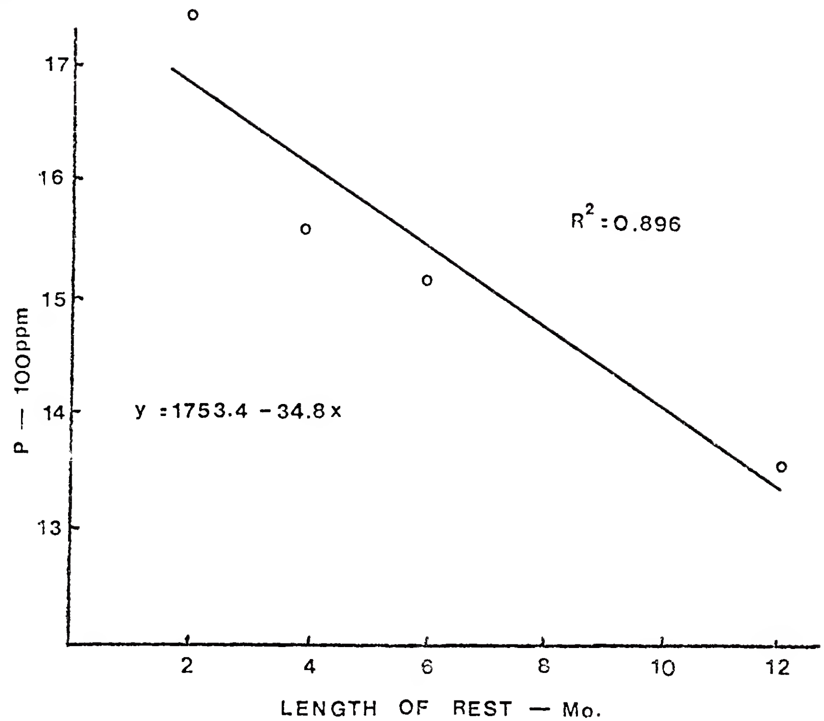

Figure 8.1. Phosphorus of selected species as a function of rest.

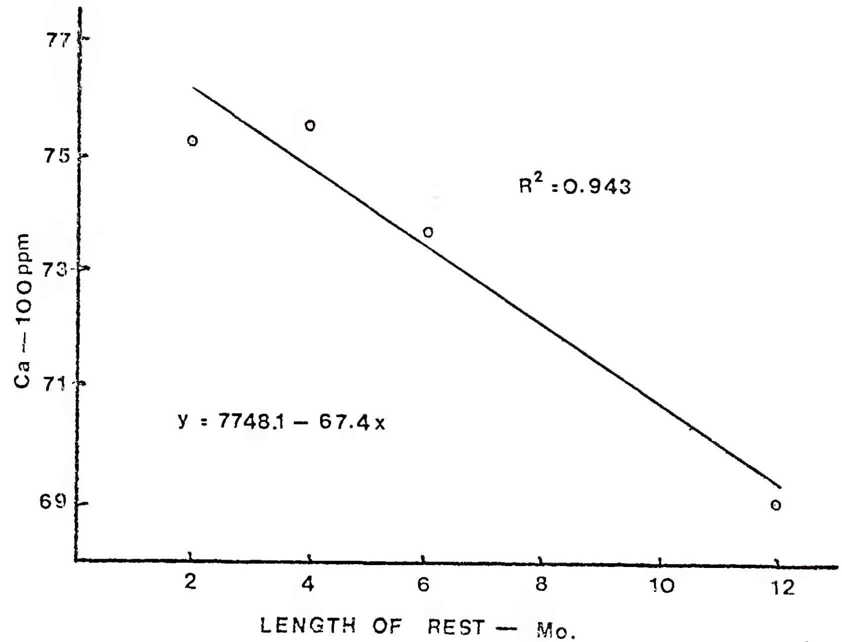

Figure 8.2. Calcium of selected species as a function of rest.

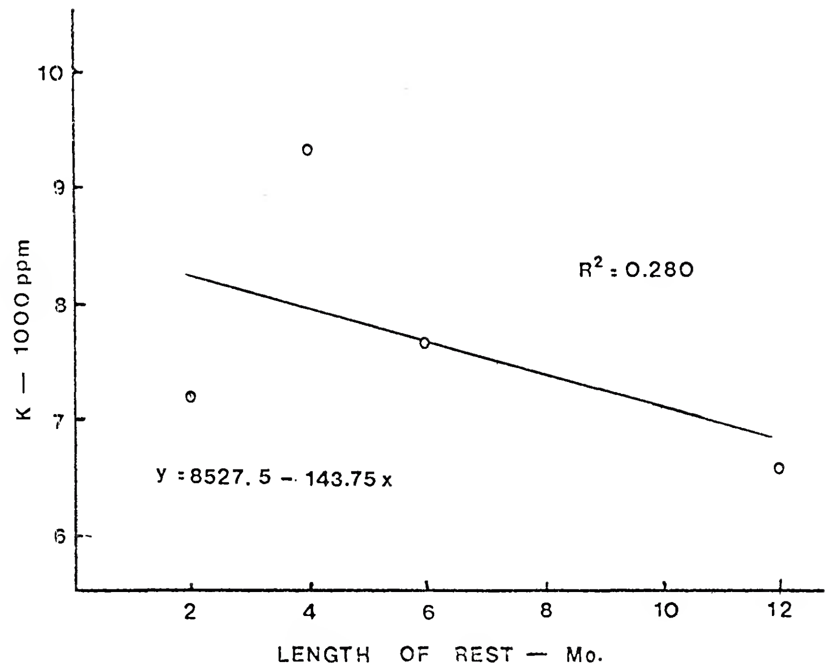

Figure 8.3. Potassium of selected species as a function of rest.

Table 8.7. Percent of species reflecting increase in chemical content (P, K, Ca) over control treatment (12 month rest).

Element	Months of rest		
	2	4	6
P	73	64	45
Ca	82	73	64
K	73	73	64

Table E.8.). For the 1977 winter collection, P was the only nutrient determined for the two-month rest and no grazing pastures in replication I. P, Ca, and K were determined for the 1978 winter collection for all pastures in replication 1, and the four-month rest and no grazing pasture in replication IV (Appendix E, Table E.9.).

In the summer collection replication effects were noted ($P < 0.1$) for Ca, Al, and Fe. Replications I and II were lower than replications III or IV for calcium. Aluminum content of replication III was higher than the others, and the Fe content of replication I was higher than the others. There were no significant treatment effects when all replications were considered. When only replications I and II (most similar soils) were used in the analysis both Mg and P showed differences at the $P < 0.025$ level with the two-month rest being higher than the no grazing treatment (Table 8.8.). Replication I and III were not found to be significant.

The 1976 winter collection showed a difference ($P < 0.001$) in P content between no grazing and the two-month rest. The 1977 winter collection had a treatment F ($P < 0.1$). The means did not separate but a trend of increased P content as length of rest decreased was noted. A linear regression (eq. 1) with P content as a function of rest had a r^2 of 0.946; Ca was 0.484, and K showed no correlation. The coefficients of the equation for P are -14.4 for the slope, 853.6 for the intercept.

Data from replications III and IV for <u>Quercus incana</u> were averaged and CV's determined (Table 8.9.). Analysis of variance indicated that potassium was lower in the two-month rest than in the no grazing pasture in replication III ($P < 0.1$). No other difference between any of the other elements were noted for <u>Q. incana</u>.

Coefficients of variation (CV) for the different species by each season (where three or more samples were used for analysis) were averaged for IVOMD,

Table 8.8. Average foliar chemical content of Pinus palustris, summer 1977 collection, replication I and II combined.

Element	Length of rest (month)[1]							
	2		4		6		12	
	X	CV	X	CV	X	CV	X	CV
P	470a	14	410	13	390	10	410	11
Ca	1090	23	1090	16	1220	15	1080	23
K	1760	28	1950	25	1790	17	2010	22
Mg	560a	17	470	13	560a	17	444	21
Al	230	11	210	21	210	25	230	29
Fe	45	57	49	95	48	39	35	45

1. Numbers followed by a letter are significantly different at $P < 0.025$ level from other treatments in same row.

Table 8.9. Foliar chemical content of <u>Quercus incana</u>, portions of replications III and IV.

	Length of rest (month)					
	2		6		12	
Element	X	CV	X	CV	X	CV
			Replication III			
P	1420	34	1330	16	1730	22
Ca	6030	11	5740	18	3310	10
K	3300a	10	3620	21	4450a	26
			Replication IV			
P	1330	16	1390	25		
Ca	5890	16	5660	13		
K	3400	22	3550	15		

Note: Number followed by same letters are significantly different at the $P < 0.1$ level.

P, Ca, and K. It was noted that the ranges of the CV's appeared to be different for the IVOMD, P, Ca, and K analyses. To check on this aspect CV's from the IVOMD, P, Ca, and K data presented in Tables E.1., E.2., E.3., and E.4. were averaged for the different species by seasons. Only those species that were represented by three or more samples per season were used. Because of the different number of samples that were analyzed for each factor, different numbers of species are used to compute each average. There was a very strong trend for the average CV of IVOMD to be the lowest followed by P, Ca, and K (Table 8.10.). Also of interest was the generally lower values obtained for summer and fall of 1977, compared to summer and fall of 1976.

Discussion and Conclusions

The data presented in Appendix E, Tables E.2., E.3., and E.4. for P, Ca, and K foliar composition of various species are offered as typical of species growing on a nutrient poor flatwoods site. It is strongly suspected, based on data given elsewhere in this document and values given in the literature (Lewis et al., 1975; Halls, 1977), that the values presented here represent the low end of the spectrum. In particular, this seems to be true for the forage species and the major overstory species (*P. palustris*). The basis for this suspicion lies in the extremely low P and K content of the soils (Chapter 4.).

Becker et al. (1957) reported foliar P content of *A. stricta* on Florida native ranges that were P deficient to be .04%. Koger et al. (1961) found foliar nutrient levels of native plants collected at the BRU to average 0.1% P, 0.24% Ca, 0.31% K, and crude protein levels of 4.8 for a four year average. It is not known where or what seasons these samples were collected at the BRU, but they are comparable to the yearly averages for 19 species collected in this study (0.1% P, 0.6% Ca, and 0.5% K). The values of P and K on the study site are, in general, much lower than those reported in the literature for other

Table 8.10. Average coefficients of variation of each season for IVOMD, P, Ca, and K.

	IVOMD	P	Ca	K
Summer 1976	15.03	27.81	36.28	40.45
# species	19	18	18	18
Fall 1976	15.39	23.96	29.81	41.47
# species	17	16	15	16
Winter 1977	13.16	22.95	24.71	33.98
# species	14	10	11	11
Spring 1977	14.61	20.29	29.01	42.76
# species	16	14	15	14
Summer 1977	14.41	14.16	23.30	53.30
# species	19	19	19	19
Fall 1977	13.30	22.77	26.41	42.68
# species	17	16	16	16
$\overline{X}$	14.32	23.67	28.25	42.44

Note: At least three samples were required before including seasonal average CV for a species. Data obtained from Tables E.1., E.2., E.3., and E.4.

type habitats, e.g. Lewis et al. (1975) in Georgia. The relationship between plant needs, foliar chemical content and soil nutrient availability are not completely understood (McLean, 1977), but it is generally agreed that the plant reflects the nutrient composition of the soil (Brady, 1974).

Observation of P. palustris in the fall of 1976 on pastures in the study site found several trees with characteristic symptoms of P deficiency; yellow cast to the needles, short retention time of needles (i.e., only one flush present). These pastures contain very low levels of extractable P. For example, pastures in replication IV treatments twelve- and four-month rest had a soil P content of 0.5 and 0.9 ppm respectively.

While optimum foliar levels of P, Ca, and K are not known for most range plants they have been determined for various crops. Normal ranges of P, Ca, and K are 0.2 to 0.3%, 0.8 to 1.2%, and 1.0 to 1.5%, respectively (Boote, 1978)[6]. A survey of Tables E.2., E.3., and E.5. (Appendix E) reveals that of the 41 species that were analyzed only five had seasonal averages higher than 0.2% of P, 22 species had foliar Ca averages higher than 0.8% and four had average K levels higher than 1.0%. While many individual values of different species were above the minimum ranges, it is of interest that so few species had seasonal averages above these values. A promising area of research would be the determination of optimal nutrient levels for range plants.

The effects of defoliation on herbaceous and woody species tends to cause losses in crude protein, P, and other minerals but a gain in structural carbohydrates as the season progresses. However, stimulation of new growth by grazing tends to retard maturity, decrease the proportion of structural materials, and increase percentages of crude protein, P, and K(Heady, 1975). The lack of increase in P on A. stricta on the before and after grazing study

6. Boote, K. J. 1978. Asst. Prof. Agronomy Dept., Univ. Fla., personal communication.

can be attributed to the short time between sampling (12 days) and the fact that March 1977 was colder than average and precipitation levels were also below average. In addition, P is generally in such short supply on this site that stimulation effects of grazing were negated.

The failure to obtain meaningful differences due to treatment effects when all replications are considered is perhaps not too surprising, in view of the marked differences in the four soil types that are found in the study site (Chapter 3). Replications I and II are the most similar with respect to soil content of Ca and K, but replications I and III are more similar with respect to P content. However, hydrology, slope, proximity to the fertilized and cultivated field, all seemingly interact with the different soil types to produce a highly variable state with respect to soil nutrient conditions and plant responses. Replications I and II appear to have more things similar than any other combination of replications; for this reason emphasis is placed on the grouping of I and II.

The eleven species sampled make up the bulk of the biomass present on the site. The use of all samples that were collected from the pastures at the completion of the grazing program provides a check on the validity of selecting only eleven species. Replications I and II show a significant difference due to treatment effects. This is reflected in the high r^2 values obtained in the regression equation for P and Ca (Figure 8.1.and 8.2.). The low r^2 value of K probably reflects the high mobility (i.e. variability) of this element.

Tests of difference in mean foliar content of the same species on a wet site versus a dry site, failed to be meaningful in only those pastures that had a common boundary. The inherent high variability of soil nutrient content in each soil type (Chapter 4), the high variability among species, inadequate

sampling procedures and the lack of sufficient sample size are the factors responsible. It is estimated that at least fifteen samples would need to be taken to overcome these variations. The differences obtained between foliar P of a pasture lying entirely within the wet site compared with a pasture entirely within a dry site, behaved as expected. However, there are some unavoidable and mitigating conditions which would tend to influence the results. There were no replications since these are the only two pastures that fit the initial requirements of lying entirely within a particular soil type and having the same treatment imposed on it. While the length of rest after grazing was the same for each pasture the length of grazing was not the same; 149 days for the wet site and 138 days for the dry site (Chapter 10). This difference in grazing time was necessary in order to remove 50% of the available forage from each pasture. This small difference (9 days) is not felt to be significant since this would only account for 0.137 Kg (an equivalent of 0.05 ppm of P added to soil profile) of the wet site through mineral supplementation (Chapter 13). This small addition to the soil profile is not enough to increase the P on the wet site by 370 ppm as recorded since it was added over a period of time through fecal droppings, and these require time to move back into the soil profile.

Systems require time to adapt to new environmental conditions with the amount of time being in direct proportion to the severity of the stress imposed (Margalef, 1968; Sanders, 1968; Horn, 1976). Since any additional P would be tied up in fecal material, it would first have to move from this environment into the soil. MacDiarmid and Watkin (1972) noted some P moved into the soil in 55 days, however this was quite variable. Studies performed in this experiment indicate a longer period of time for substantial amounts of P to move into the soil profile (Chapter 12). It would appear that the

results noted are valid and the difference in the foliar P content of the wet site noted above reflects the higher P in the soil profile.

McFee et al. (1977) have reported that foliar content of N and P in P. elliottii have cyclic seasonal variations with highs in winter and lows in summer. This same effect has been noted in P. palustris during this study. Dilution effects as explained by McFee et al. (1977) are believed to be responsible for the lack of treatment effects noted for the summer collection. Only K was higher in the no grazing treatment than in the two-month rest, all the others were the same or higher in the two-month than in the control. Both winter collections show an increase in foliar P for the two-month rest over the no grazing treatment (Appendix E, Table E.9.).

The implications of these results argue for the presence of livestock in mature stands of P. palustris, particularly on nutrient poor sites, as being beneficial to the increased foliar concentration of nutrients in the trees and thereby improved health of the stand. While some paper companies (Container Corp. of America, Ackerly, 1977) are leasing their timbered land for cattle grazing, most do not. While there may be excellent reasons for excluding livestock on timber operations, the main bias against livestock seems to be the extended barrage of early publications put out against grazing woodlands from almost all governmental agencies (Mann, 1947; Morrow, 1955; Williams, 1951). The basis of this belief lies in the fact that over utilization of an area by livestock can cause damage to trees. The problem lies in management, not in livestock per se.

Minimum levels of foliar mineral concentrations for pines have been determined for the various nutrients (Ballard, 1974; Richards and Bevage, 1972) and regression equations have been developed for predicting how much of a particular nutrient is contained in a given part of a tree (White and Pritchett, 1970). However, there is no method to quantify how much added growth will result from

an increase in any one particular nutrient. Growth and yield curves have been determined for P. palustris plantations, however minimum growth requirements are usually assumed to have been met, and such curves are based on initial spacing, density after thinning, and age of stand (Lohrey, 1974).

Interpretation of the data from Table 8.9. requires an understanding of the methods used to calculate the CV's that are being averaged. Since the CV's are being separated as to seasons, the variations between seasons are removed. Variations within season (different sampling dates), within species, between species, phenological development (the samples were not sorted as to maturity), and variations due to the fact that some samples were composited and some were not, are included in these data. It is believed that the inclusion of these variations allows a realistic picture to be developed concerning the various interactions of the site on the plant as reflected by the foliar chemical content.

The hypothesis being tested is that in a site where a particular nutrient is limiting, the variation of that nutrient in the foliage is less variable (lower CV) than those nutrients that are not limiting plant development. The basis for this lies in the assumption that the plant, when it acquires an additional amount of the limiting nutrient utilizes that element in new growth (Loneragan, 1973), consequently, maintaining approximately a constant ratio of nutrient to biomass. Whereas if the nutrient is not limiting, then luxury consumption occurs (as in the case of K) and some plants of the same species contain more of that nutrient than others. There is also more variation of that nutrient when all species are compared than if the nutrient is limiting. Calcium is relatively immobile, where the amount in the foliage is a function of maturity being left as a residual of the transpiration process over time (Charley, 1977). In a non-limiting situation, Ca is expected to have high variability, especially as the growing season progresses. The more mature

plants have greater concentrations than the younger plants. Under limiting conditions, foliar concentration of Ca would be limited by root absorption rather than transpiration (Loneragan, 1973).

The data in Table 8.9. tends to substantiate this hypothesis. The major limiting nutrient of the study site is P, which is the only nutrient that showed a strong correlation with the soluble counterpart in the soil ($r^2 = 0.63$).

Calcium also has a fairly low average CV, which indicates that this element is also in short supply with the plants tending to incorporate into biomass any Ca that is picked up. Potassium, on the other hand, shows a high level of variation, except in the winter when metabolic activity is slowed. Since only four species rank higher than the crop minimums for K foliar content, this indicates that range plants seemingly require a lesser amount of K for optimal growth, disregarding any interactive effects with other nutrients.

The use of CV to evaluate limiting nutrient is believed to be unique in soil foliar nutrient analysis. Terman (1977) has used this type of procedure in justifying composited replicates in a nutrient uptake study.

Since IVOMD fails to show any correlation with any single nutrient (Chapter 7) but does show a weak correlation when two variables (P and Ca) ($r^2 = 0.44$), it is not too surprising that the variability is the lowest of the four quntifiers tested (IVOMD, P, Ca, and K). This further argues that IVOMD is a function of a number of factors and if any one of them is limiting the percent digestibility can be expected to be low.

Based on the above and previously discussed data, it is concluded that P is the major limiting element of the site. The hypothesis that the limiting element can be determined from an analysis of the CV needs further clarification with specific experiments designed for this purpose. Since virtually nothing is known about the nutrient requirements of range plants, CV could become an important tool to aid in that diagnosis.

When all the samples are used to estimate the composite foliar P for each pasture at the beginning of the experiment, no differences are noted for treatment effects, however there are block effects. When only replications I and II are used, there are no replication effects. Thus two conclusions can be drawn: first, the treatments started without bias, and second, there are block (replication) effects and these are primarily due to the inclusion of replications III and IV. When the foliar P content is similarly analyzed at the end of the experiment there is an effect noted ($P < 0.1$), between treatments. Again, when only replications I and II are combined there is still a treatment effect but no replication effects. While the treatment effects are at the $P < 0.1$ levels the block effects are at the $P < 0.05$ level. From the above it appears that there are treatment effects, however the effects due to the physical location (soil) are larger. This further argues for the case of considering only replications I and II as being the most comparable with respect to all elements except P, and replications I and III being the most comparable with respect to soil P.

Forage reaction to grazing stress can follow two paths depending upon the severity. Moderate grazing stimulates plants to increased production while heavy grazing reduces plant vigor. However, grazing pressure was the same on all pastures (50% removal of available forage) and length of rest is the variable. Cubillos (1976),working with Cynodon nlemfuensis in Costa Rica found that the length of time for a pasture to replenish its stores is related to the stocking rate (the amount of dry matter per animal per day for a given unit of land). However, the stocking rate in this experiment was adjusted by the use of the grazing period (five to nine days) necessary to remove 50% of the forage. This small variation in the length of time that the animals were left on the pastures is assumed negligible and length of rest considered to be the only variable. The length of time that a plant

requires to recover from defoliation is dependent on the species concerned, severity of defoliation, fertility, and other environmental factors related to the site (Heady, 1975).

Competition between the grazables and ungrazables is also a factor. Since P is limiting on this site, it is assumed that the majority of the competition is concerned with the uptake of P as it is made available in the soil profile. Consequently, competitive effects between plants might be mitigated by addition of nutrients such as mineral supplementation to livestock.

Factors that affect the six-month rest treatment are that grazing occurred during the winter and summer. Plants were dormant during the winter with little growth occurring. Growth slows in the summer under normal conditions and the rainfall pattern of 1977 was 37% below normal (Chapter 3). When grazing occurred on the six-month pastures (July), the plants were in a dormant state. However, on the two- and four-month rest pastures the plants were grazed during the spring when there was still soil water available from the above normal winter rains. After being grazed the plants were faced with dwindling supplies of soil water, and thus being doubly stressed failed to respond, as perhaps they might have under a more normal year. In this respect, the areas that did respond were those pastures to the east side, closest to the creek and the shallower water table. This is reflected by the high replication average for relative percent change of foliar P found in replications II and IV (Table 8.5.).

There appears to be an interactive effect involving soil P, soil water, grazing stress, ability of understory plants to recover a larger portion of the fecal nutrients, and perhaps soil type. This is particularly evident if only replications I and III are considered, since soil P levels of these two blocks appear to be similar even though they are of different soil types. As

an example, in replication I the soil water is assumed to have been depleted first on the west side of the site then grading toward the east (Chapter 13). The six month rest pasture is low in P (2.7 ppm) and was not grazed during the growing period. The two-month pasture had a higher soil level of P (8.3 ppm), therefore plants did not respond as dramatically to the increased P applied (the closer to the optimum the lesser the response) and were grazed twice during the growing period when soil water was also becoming limited; the four-month pasture had a low level of P (1.7 ppm), had the lowest level of applied P, and was also grazed during the growing period, thus resulting in the ranking of six-, two-, four- and twelve-month rest. The same line of logic could be applied to the other replications, with the eastern replications having the added factor of lingering soil water due to the proximity of the creek and recharge when rainfall exceeded 2.5 cm (Chapter 13).

There appears to be a correlation for foliar P and the extractable P in the soil profile (top 30 cm). Interestingly, the correlation is weakest for P. palustris ($r^2 = 0.2$) and 0.4 for Q. incana then increases as more and more species are included in the total tally. The pines are fairly mature trees (20 to 30 years old), with well developed root systems. This extensive root system allows the tree to exploit a much larger area than the smaller and younger Q. incana, or the smaller understory that are increasingly represented as the samples groups get larger. The larger root system of trees would tend to mask the local effects of soil micro-variability (Chapters 4 and 6). Local soil variability would take on larger importance the smaller the plant and the consequent lesser soil volume it exploits.

The above discussion concerning the various facets of mineral effects on plants, ignores one major nutrient, nitrogen. Only 21 species were analyzed for N, and none of these were monitored over the different seasons. Some idea

of the amounts of atmospheric inputs of N are known (Chapter 13), but soil content is not known. Based on crude protein determinations made by Young (1977) and Koger et al. (1961) and this study, indicate that the N content of the plants is low. It is not known whether this is typical of the range plants on this site, nor what are the threshold levels of N for Florida range plants. If N is also limiting, interactions with P, Ca, and K would further confuse the picture. As Terman and Nelson (1976) have pointed out, soil fertility is a complex multi-factor situation, and often it is uncertain which nutrient is the dominant or limiting one.

The concept of limiting factors from Liebig, Blackman et al. have been reviewed by Evans (1975) and Mitsch (1975). The evolution from a simple additive model to a multiplicative model to the multifactorial analysis has been noted by Etherington (1975). With the advent of the large computer, response surface designs are not being used to evaluate agronomic experiments (Littell and Mott, 1974). From these analyses, it has been noted that the addition of any one of two limiting nutrients will cause an increase in yield (Melsted and Peck, 1977), although the Steenbjerg effects may mask this response (Bates, 1971; Larcher, 1975).

A true picture of what is occurring on the study site with respect to minerals is not fully defined. A study set up as a response surface design, with various increments of suspected nutrients added, might go a long way toward defining what are the minimal amounts of nutrients that range plants need. This type of investigation coupled with a forage quality evaluation would provide much needed information to the various producers that utilize the rangelands of Florida.

CHAPTER 9

UNDERSTORY HERBAGE PRODUCTION

Introduction

Forage production measurements are the mainstay in the determination of proper utilization in any forage system (Shaw et al., 1976) and are especially critical when livestock are involved (Heady, 1975; Stoddart and Smith, 1955). Two general biological systems are involved in forage production and utilization: 1) the environment-plant and 2) the plant-animal systems (Matches, 1970). The system studied here is the plant-animal type. Plant-animal systems are of two general categories: 1) pasture systems and 2) rangelands. Methods for measuring production in pastures have been well studied and numerous references exist as to methodology (Shaw et al., 1976; Mott, 1973; Spedding, 1971). Similarly, considerable information exists as to measurements under Western range conditions (Heady, 1975; NAS, 1968; Stoddart and Smith, 1955).

Woodland grazing has existed for a long time in the Southeastern United States (Campbell and Biswell, 1945) and was, for the most part, discouraged (Morrow, 1955; Williams, 1951). Consequently, little effort was made to determine proper measurement techniques for the Southeast until 1958 (Southenr and Southeastern Forest Experiment Stations Sumposium, 1959).

On a regional basis, there have been efforts to define methods that are appropriate to Florida conditions. Leithead (1973) groups woodlands into suitability classes concomitant with four different overstory types by using soil surveys as a basis. Southern foresters have long had methods for estimating yield of trees and numerous equations exist (White and Pritchett, 1970;

Bennett and Clutter, 1968; Forest Service Staff, 1976). White (1975b) has defined some of the problems associated with sampling in plantation pines on the Florida Coastal Plains, as well as giving indications of response of the understory vegetation to various modes of site preparation.

Ecologists have used different methods to evaluate woodland ecosystems. Harcombe and Marks (1977) used a vertical column, coupled with circular plots, in an understory study in East Texas. Woodwell and Whittaker (1968) used dimension-analysis to measure uneven age natural forest, and Ovington (1965) used the concept of an "average tree" for measurements on even aged stands. The major aim of ecologists, however, has been to measure gross primary production in forested ecosystems (Olson, 1975). Primary production measurements involve a realization of all of the components of an ecosystem: decomposition, herbivory, litter production, primary production, etc., and require at least an estimate of the contributions of each (Coupland, 1975).

The harvest technique is best applied to fields, grasslands, and tundra, but is not too applicable to forest, especially when the overstory component is to be evaluated (Woodwell and Whittaker, 1968). The major reason for the distrust of the harvest technique, aside from the difficulty of harvesting trees, lies in the competitive effect of the overstory on the understory (canopy effects). This is manifested by competition for sunlight, moisture, nutrients, and the consequent buildup of overstory litter on the understory plants. If the overstory biomass is not to be monitored, application of the harvest method to the understory is about the only practical alternative.

The effects of natural herbivory on herbage can be considerable and must be accounted for when discussing ecosystem production (Chapter 10). Herbage consumption is usually measured by estimating difference of yield in grazed and ungrazed areas. Best results are obtained if the animals do not remain

in the pasture more than four to six days (Mott, 1973). This allows a minimum of regrowth to occur that might otherwise confound the results.

Grazing pressure is defined as the actual animal-to-forage ratio at specific times (Range Term Glossary Committee, 1974). Cubillos (1976) has defined grazing pressure as the number of animals to a unit of land, relative to the available forage. The second definition is not as time dependent as the first and allows time to be used as a variable in adjusting animal numbers, pasture size, supplementary feeding, or harvesting excess amounts as discussed by Mott (1960).

Stocking rate, the amount of land per unit animal for the entire grazing season (Range Term Glossary Committee, 1974), has long been held to be the key for proper utilization of rangelands. However, the assumption that plants can be grazed to a proper level through regulation of stocking is unrealistic because of the selective grazing habits of livestock (Hormay, 1970). Merrill (1959) has reported the deterioration of a Texas range when stocking rate was the major criterion. This realization has led to the development of various grazing systems involving the degree of rest between grazing applications. In effect, this is attempting a small scale duplication of the natural patterns of grazing by wild ungulates in natural grasslands such as discussed by Lamprey (1963) and Harris (1972).

There are numerous grazing systems, most of which have built into them a degree of rest from grazing. The total spectrum of benefits claimed by the various proponents of the different plans is seldom realized, although it has been established that scheduled rotational grazing does benefit the range (Heady, 1975). Such plans need to be tailored to a particular region, or local environment.

One such system that appears to offer promise in sub-tropical Florida was developed in Texas and has been used on commercial ranches in that state

(Norris et al., 1975). This system, the short duration-high intensity grazing system, is relatively flexible, in that the duration for the animals to stay in a pasture is based on the amount of forage in that pasture and desired utilization, usually 50%. Attempts are made to adjust cattle numbers so that grazing will last between 20 and 60 days per pasture, with a complete rotation in 5 to 12 months. There is no set sequence of pasture use, however the best pasture is always the next pasture grazed (Norris et al., 1975). This type of system is currently being investigated in South Florida with indications of success (White, 1978)[7].

At first glance the environment of Florida appears to be relatively uniform, however the high rainfall, sandy soils, lack of relief, all tend to provide an environmental mosaic which is highly variable. Sandy soils simply do not hold nutrients as well as other types of soil (Brady, 1974). The low nutrient content of Florida soils (Blue, 1970; Pritchett, 1968; Yuan, 1966) has resulted in mechanisms that might go unnoticed in more benign soils, resulting in increased local variability of nutrient content in the generally impoverished Florida flatwoods soils (Chapters 4 and 6). Such local variations manifest themselves on the smaller understory plants, resulting in high variations of growth within species in a small area.

The following represents one type of approach that was used to determine production on a Florida range flatwoods along with recommendations for improvement.

Materials and Methods

The sampling procedure was given in Chapter 3 but will be briefly reviewed here since it affects the outcome of this portion.

7. White, L. D. 1978. Assoc. Prof. Range Mgmt., Univ. Fla., Personal communication.

There are several different methods used for estimating production of grazing systems. The one selected for this study was a modified harvest technique, using a herbage meter to estimate the amount of forage present before and after a grazing application. An electronic capacitance meter (Neal herbage meter #18-2000) was used to monitor the amount of herbage in each quadrat. Methods of use were taken from Neal and Neal (1973) and Currie et al. (1973). Based on favorable reports on the use of capacitance meters to measure shrub type vegetation (Carpenter et al., 1973) it was decided to incorporate this method into the study.

Forty rectangular 0.9 m^2 permanent quadrats (2 ft^2) were established in each pasture along four north-south transect lines. Each line was equally spaced across the pasture with 10 quadrats per pasture.

Selection of which quadrats to clip was made on the basis of the herbage meter readings for all 40 quadrats. Each quadrat was identified as moist, wet, or dry each time a measurement was taken. Sampling occurred prior to cattle entry and again after their removal from each pasture. Initially eight quadrats were clipped. Starting in November 1976 only four quadrats were clipped. This was continued until June 1977 when eight quadrats were again clipped. This resulted in the final clipping of the four-and six-month pastures to be represented by four quadrats, while the control and two-month pastures are represented by eight quadrats. The clipped plots were sorted as to species (large woody material removed) and litter. Field species identification was confirmed when the species were weighed in the laboratory.

Pasture production was estimated as a function of time, and total production calculated. Three calculations of this type were made: the first used the individual regression equations developed on the basis of the herbage meter reading and clipped plots for each pasture at that sampling period. The

second was based on a single regression equation, developed for each pasture and habitat type within that pasture, over the duration of the study. Some pastures had three separate regression equations for herbage determination, based on the percent of each type of site (wet, moist, and dry) that occurred in the pasture. A third and final calculation of production was made, based on the best regression line that was developed for that particular pasture (the single time equation or the year long composite).

Selection of the best regression equation was subjective; if there were no significant differences (t-test) associated with the equation, or if there were two or less degrees of freedom, the single regression equation was used. If there were five or less degrees of freedom, whichever equation had the higher level of significance was used. For degrees of freedom higher than five, whichever equation had the higher level of significance, or if this was the same, the one that had the higher r value was selected.

Not all pasture sampling was initiated on the same day, nor did they all finish at the same time, e.g. the six-month treatment finished about two months ahead of the two-month treatment (Appendix A, Table A.1.). This discrepancy in starting and finishing dates, as well as different sampling dates during the year, presented some difficulty in attempting to compare the different treatment effects.

Two approaches were attempted to resolve this conflict. One method selected a starting day (the 238th day from 1 January 1976) and finishing day (564 days since 1 January 1976) that was common in all cases. Forage values were selected from plotted curves, corresponding as close as possible to actual sampling dates, and changes in biomass noted. This method has the advantage of starting and ending at the same time with a uniform experimental period for all treatments (326 days). However, some increments of growth and utilization fall outside of these dates for some pasture-treatment combinations.

The other method compared the control pasture (twelve-month rest), with each of the other treatments on a case by case basis. Thus, in the case of the six-month rest only those control sampling points that correspond, timewise, to the sampling dates of the six-month treatment were used. The two- and four-month rest treatments were treated similarly. This has an advantage in that the dates of sampling are approximately the same. However, the different treatments have different periods of growth to be included in the total production value since the starting and ending dates are different. This makes comparisons between treatments difficult. In both cases only positive increments of growth are recorded. Biomass is computed based on the difference between the low (generally in March 1977) and the highest amounts observed, plus that amount removed by the cattle, not accounted for in the high readings.

Functional groupings (grasses, forbs, shrubs, trees, total biomass and litter) were made of this data for the initiation of the experiment (summer 1976) and the conclusion of the experiment (summer 1977) (Appendix E, Table E.10.). Since the litter component was consistent in the number of samples (eight per pasture for each sampling date) a t-test was used to test for significant differences ($P < 0.05$).

Unpublished data (Moore, 1978)[8] were used to determine frequency data of the site. Data was collected in August 1976 and August 1977. This study had four 30.5 m (100 ft) permanent line transects per pasture with each transect divided into 15 cm (6 in) intervals. Frequency of leaf counts were used where a hit was recorded if a leaf occurred anywhere within the interval. Only one hit per species per interval was noted. A description of this technique may be found in Basic Problems and Techniques in Range Research (NAS, 1962). From

8. Moore, W. 1978. Adjunct Prof. Sch. of For. Res. and Consv., Univ. Fla.

this data, diversity indices (H') were calculated using the Shannon Wiener formula (eq. 4). Evenness (J') was determined from equation 5. Two determinations of these parameters were made, August 1976 and August 1977. Determination of diversity for different functional groups, e.e. grasses, forbs, and shrubs, were also made.

On 29 June 1976 one 30 m line transect was laid out in a random manner in the control (twelve-month rest) and the two-month rest pastures in all replications. The leaf intercept method was used with frequency of occurrence recorded as a function of total hits per line. Functional groupings as well as individual species were used with appropriate statistical methods to determine treatment effects. Species diversity parameters were also calculated for this data.

In addition, two overstory parameters were of concern: percent of canopy cover and basal area. Estimates of percent cover were averaged by ocular estimates for three positions (middle of transect and each end) along each of the four permanent line transects in each pasture. The average basal area was determined by the use of a 10 factor variable prism. The same positions were used as in the canopy cover technique.

Linear regression (eq. 1) and multiple regression (eq. 2) were used to relate production of soil P content. Various combinations of pastures were used for this comparison.

Results

Time of sampling for each pasture, the percent of wet, dry, and moist area in each pasture, and amount of herbage present (based on the best regression equation developed) are presented in Appendix A, Table A.1. The amount of herbage that was estimated from the regression equations developed at the time of sampling, as well as the year end composite equations, are not presented since they were extreme in their predictions of herbage present.

Biomass production of replication I (all treatments) shows the anticipated seasonal decline, as well as some of the difficulties encountered with the sampling procedure, e.g. more biomass present after the cattle had grazed the pasture than was present before (Figure 9.1.). Replication I exemplifies the typical forage response as well as problems encountered in sampling procedures.

Using the relative percent change in biomass from summer 1976 to summer 1977 (Appendix E, Table E.10.) no meaningful differences were detected for either treatment or blocking effects for any of the functional groups except litter.

The litter component was found to increase ($P < 0.05$) in all pastures except replication I, four-month rest. No treatment or block effects were noted. The average CV for summer 1976 was 59.9 and dropped to 47.4 for the 1977 data.

Numerous statistical tests were made on each species, but no statistical relevance was forthcoming. Some general trends appear to be worth noting. Total live biomass of the understory appears to be decreasing in all replications except IV. Shrubs and trees seem to be increasing in replications III and IV. Grasses appear to be increasing in all but replication II and forbs are generally decreasing in all replication.

Calculations of the biomass produced, for each treatment based on the uniform experimental period (326 days), indicated that the two-month produced more forage than did the control (Table 9.1.). Linear regression (eq. 1) used to relate forage production as a function of length of rest resulted in r^2 to 0.918 for replication I (4 points); r^2 of 0.707 for combinations of replication I and II (8 points); and r^2 of 0.568 for the average of all replications (4 points).

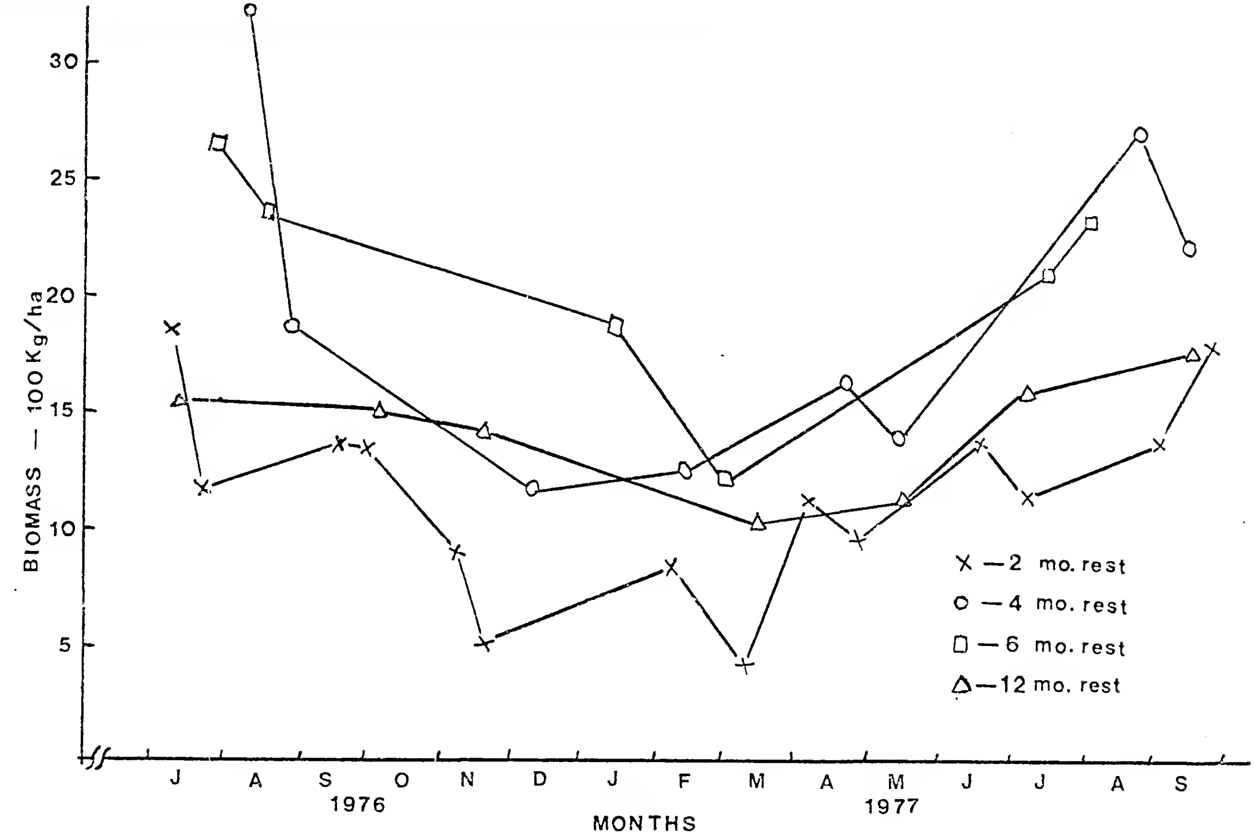

Figure 9.1. Standing crop, all treatments, replication I, for the study period.

Table 9.1. Forage production (Kg/ha) based on uniform length of experiment (326 days: 23 August 1976 to 18 July 1977).

Replication	Treatment (months rest) 2	4	6	12
I	2987.2	2120.9	2098.6	1116.5
II	3305.9	1649.0	1984.3	1402.4
III	3074.8	1176.2	1302.6	1070.1
IV	2418.5	1979.4	3648.4	2377.7
$\bar{X}$	2946.6a	1731.4ab	2258.5ab	1491.7b

Trt F = 3.860 significant @ $P < 0.05$.

Blk F = 0.993 ns

Note: Numbers followed by the same letter are not significant at the $P < 0.05$ level.

Comparison of each treatment with the control (Table 9.2.) by the use of a t-test indicated an increase of forage in the two-month treatment compared to the control ($P < 0.01$); no other meaningful differences were noted. Separation of means by treatment, indicated that the two-month rest was higher ($P < 0.05$) than the other treatments over all replications followed by six, four and control.

Diversity indices (H') calculated from the four permanent line transects per pasture show significant replication effects with replication II being lower for the summer 1976 sampling (Appendix E, Table E.1.). Number of species were also lower but were not significant. Summer 1977 data (Appendix E, Table E.12.) indicated differences ($P < 0.01$) for H' and J' with replication II being lower than the rest. Number of species was also lower for replication II but were not different. There were no treatment effects noted in either 1976 or 1977.

The possibility of detecting changes in the community composition through the use of diversity indices over the experimental period was investigated. Relative percent changes were determined using the 1976 data as base (Table 9.3.). No treatment differences were noted for H', however there were differences in replications (replication II had the highest percent decrease). The six-month rest showed a higher increase in species number. Replication II showed a decreasing trend in the evenness component with no treatment effects.

Frequency of leaf hits were determined from the four line transects in each pasture for each specie. These data were averaged for all replications and are presented as a function of treatment (months of rest) for the initial collection in September 1976 and the final collection in September 1977 (Appendix E, Table E.13.). Relative percent change from 1976 to 1977 were calculated for functional groups and are presented in Table 9.4. Trees showed

Table 9.2. Production (Kg/ha) for treatments compared to control samples taken at same time as the particular treatment.

Treatment	Replication						
	I	II	III	IV	$\bar{X}$	t value	LS[1]
2 month	3359.5	4567.1	3317.1	3978.0	3805.4	4.037	0.01
Control	1268.0	1721.3	1325.8	2960.2	1818.8		
4 month	3873.5	1305.6	1384.8	2517.7	2270.4	1.138	0.30
Control	1077.9	1155.2	182.8	2898.6	1328.7		
6 month	2383.9	1605.9	1441.7	3885.6	2329.3	1.456	0.20
Control	1113.6	1666.2	843.3	2069.5	1423.2		
Average of controls	1153.2	1524.3	784.0	2642.8	1523.6		

ANOVA results using control average.[2]

Trt F = 5.455 sig. @ 0.01

Blk F = 2.512 sig. @ 0.10

Duncans mean separation (P 0.05)

12	4	6	2
<u>1523.6</u>	<u>2270.4</u>	<u>2329.3</u>	3805.4

1. Level of significance.
2. There were three degrees of freedom for treatments and blocks and nine for error.

Table 9.3. Relative percent change in species diversity from summer 1976 to summer 1977.

Treatment month rest	Replication I	II	III	IV	$\bar{X}$
			H'		
2	-13.28	-44.29	-5.38	- 6.70	-17.41a
4	- 4.32	-11.93	-0.60	-10.31	- 6.79a
6	- 7.84	-11.98	3.35	-12.10	- 7.14a
12	- 8.62	-18.27	-3.26	-14.81	-11.24a
$\bar{X}$	- 8.52a	-21.62b	-1.45a	-10.98ab	
	Trt F = 1.638		Blk F = 4.676*		
			spp		
2	- 6.8	4.8	10.4	0	2.1a
4	- 4.0	-4.7	8.9	- 2.2	-0.5a
6	14.0	14.6	13.3	14.3	14.1b
12	2.0	5.0	-4.0	- 2.1	0.2a
$\bar{X}$	1.3a	4.9a	7.2a	6.8a	
	Trt F = 6.682*		Blk F = 0.976		
			J'		
2	-11.6	-45.0	-7.7	- 6.7	-17.8a
4	- 6.9	-10.8	-2.8	- 9.8	- 5.3a
6	-10.9	-15.0	0.6	-15.1	-10.2a
12	-9.1	-19.3	-2.2	-14.3	-11.2a
$\bar{X}$	-9.6a	-22.5b	-3.2a	-11.5ab	
	Trt F = 1.163		Blk F = 4.040*		

*Significant at $P < 0.05$ level

Note: Numbers followed by same letter are not significant at $P < 0.05$ level.

Table 9.4. Relative percent change in leaf hits on line transects for the average of all treatments from September 1976 to September 1977.

Herbage group	Months rest			
	2	4	6	12
Trees	97.6	45.2	24.2	44.4
Shrubs	-8.7	13.5	12.5	5.3
Vines	-37.3	71.8	3.8	0
Grasslikes	-50.7	-36.4	-51.3	-66.7
Grasses	52.1	43.4	35.5	31.9
Ferns	-59.2	-53.6	-40.4	-49.1
Legumes	-82.7	-74.3	-73.1	-82.8
Forbs	-28.6	-16.1	-22.7	-4.3
Litter	29.0	75.2	23.2	-29.4
Bare ground	-100.0	-100.0	-88.6	-100.0
Total leaf hits	-19.6	-19.7	-16.1	2.5

Note: Original data collected by W. H. Moore, Adjunct Professor, School of Forest Resources and Conservation, University of Florida.

a general increase in all treatments, largest in the two-month rest and declining as the length of rest increased. Grasses also followed this same pattern. The grasslikes, ferns, legumes, and forbs showed a decline in all replications. The vines were erratic with a large percent loss in the two-month, a large gain in the four-month, and little change in the six-month and control. The amount of bare ground decreased almost 100% in all treatments and litter increased in all but the control pasture where it decreased. The total number of hits decreased in all pastures except the control where a slight increase was noted. Litter and bare ground were the only groups that were found to have a significant change.

Diversity indices calculated on the 30 m line transect (Table 9.5.) showed no differences between the two-month rest and the control (t-test). However, replications I, II, and III showed higher values for H', species richness, and J' in the two-month rest than in the control. Replication IV was just the opposite.

Analysis of the overstory components indicated that the two-month treatment had higher basal area than the control or six-month rest ($P < 0.05$). There were no block effects (Table 9.6.). No effects were noted for canopy cover. Efforts to relate canopy cover to grass and total production data, both at the beginning and at the end of the experimental period, using both the data from the regression predictions (Appendix A, Table A.1.), and from the clipped plots (Appendix E, Table E.10.), failed to produce relevant results. When the canopy cover was compared from replications I and II, by the use of a linear regression equation to the clipped plot biomass estimates, correlation was attained ($r^2 = 0.63$).

When all replications were used in developing linear equations relating production to soil P content, the r^2 was 0.17. When each replication was used individually the r^2 values were 0.35, 0.79, 0.58, and 0.87 for replications

Table 9.5. Diversity indices from 30 m line transects of control and 2 month rest pastures.

Treatment	Replication				
	I	II	III	IV	$\bar{X}$
			H'		
12	1.344	0.977	1.338	1.235	1.224
2	1.234	1.198	1.272	1.337	1.260
			spp		
12	42	38	37	45	40.5
2	43	40	40	43	41.5
			J'		
12	.828	.618	.853	.747	.762
2	.756	.745	.794	.819	.779

Table 9.6. Overstory characteristics of the study site (all trees).

Treatment month rest	Replication I	II	III	IV	$\bar{X}$
			Basal area (m^2/ha)		
2	8.71	8.13	6.51	7.08	7.61c
4	6.79	6.70	6.51	6.79	6.70abc
6	6.32	5.93	5.84	5.55	5.91ab
12	5.07	5.17	5.84	6.51	5.65a
$\bar{X}$	6.72a	6.48a	6.18a	6.48a	
	Trt F = 6.895*		Blk F = 0.446		
			% Canopy Cover		
2	62.8	53.0	38.0	62.5	54.1a
4	39.3	57.0	51.6	58.0	51.5a
6	46.4	35.0	56.1	69.3	51.7a
12	43.3	27.8	42.4	61.8	43.8a
$\bar{X}$	48.0a	43.2a	47.0a	62.9a	
	Trt F = 0.756		Blk F = 1.863		

*Significant at $P < 0.05$ level.
Note: Numbers followed by same letter are not significant at $P < 0.05$ level.

I, II, III, and IV, respectively, and was .57 when replications I and II were used. Multiple regression (eq. 2) relating production to percent canopy cover and soil P content had a weak correlation when all replications were used ($r^2 = 0.22$), but when only replications I and II were considered, the r^2 was 0.58.

Discussion and Conclusions

Both methods of computing production gave the same rank order with respect to increased production (in ascending order, control, four-, six-, and two-month rest). This same trend was noted in the foliar P content (Chapter 8). The six-month rest appears to be out of place. Linear regression equations developed with production as a function of length of rest show a strong correlation especially for replication I ($r^2 = 0.92$). The r^2 was lower when other combinations of replications were used, but were above 0.5. This indicates treatment effects are influencing the production.

There are a number of factors that are interacting besides increased P in fecal droppings, number of cow days spent on the different treatment. The six-month treatments were grazed only in the dry summer and winter and not during the actively growth periods as were the other pastures, as discussed in Chapter 8. Basal area of trees in the six-month treatment in replication II, III, and IV are lowest of all treatments and percent canopy cover is below the average for the six-month treatment in replication I and III (Table 9.5.). The rainfall was below normal, which resulted in a lowering of the water table. This drop of the water table occurred first in replications I and III, followed by replication II and IV, respectively, due to the proximity of the creek (Chapter 13). The soil P content of the six-month treatment was highest in replications I, II, and IV, and above average in III (Chapter 4). All of these factors interacting tend to make the pastures where the six-month rest treatment was imposed, a naturally more delightful place for understory plants to live.

Soil P levels are the predominant factor of herbage production with other factors acting in a minor capacity. The optimal length of rest for grazing a native flatwoods range will be discussed in the conclusion section (Chapter 15).

The diversity indices analysis indicates that replication II is significantly lower than other replications for both 1976 and 1977. This is due to fewer species present and lower evenness (J') components. This same effect is noted in relative percent change (Table 9.3.). Replication II has the highest rate of change, most of which is due to the J' component. Both replications that lie to the east (II and IV) are undergoing fairly rapid change in community structure. Even though new species are being added, the evenness component is decreasing, thus implying that while there are numerous species present, most of the community is made up of a few dominants.

The results of the frequency analysis indicates that there is a trend toward a natural change, above and beyond that imposed by the grazing treatments. Of the 11 groups considered, six of them demonstrated large changes in the control pastures. The legumes and grasslikes had the largest decrease in the control pastures. The grasses are apparently increasing in all species, but wiregrass is the largest increaser in all treatments (Table E.12.). Trees also are increasing, however _Q. incana_ is the species primarily responsible. This increase in the grasses is difficult to fit into the canopy cover model proposed by Halls (1955). A possible mechanism will be discussed later.

An explanation for replication II and, to a lesser extent, replication IV becoming less diverse (through a rapid decline in the evenness component which offsets the modest gains in species numbers), is a combination of physical properties and location. Replication II contains three different soil types (Chapter 3) lies in a close proximity to the creek and is bounded to the north by a cornfield. Replication IV only has two soil types and located far from

the cornfield, but the creek is much closer. The predominant soils in both of these replications are normally wet much of the year. The rainfall during the experiment was 37% below normal (Chapter 3). This was reflected by the lowering of the water table to depths greater than 1.2 m in replication II; pastures in replication IV had water at 1 m or less throughout the course of the study. This water stress occurred in all pastures and is responsible for the lower J' values noted. In the case of replication II, the community is more mesic than replication IV; also, this area has a more level topography than IV and also a soil type associated with a wetter environment, but lost soil water earlier than replication IV due to its greater distance from the creek. This replication also borders the cornfield and would obtain some nutrient drift from this association. This would tend to reduce the role of nutrients and raise the importance of water as the major limiting factor. Thus, when the water stress developed, the hardest hit community was the more mesic one and the diversity index dropped, at least temporarily. This concept is generally true when any stress impacts a community (Odum, 1971).

One realistic trend was that the litter component was increasing in all but one pasture, during the duration of the study. This, perhaps more than any other factor, explains the general trend of a decrease in biomass of the understory for all but replication IV. Replication IV, because of its proximity to the creek, appears to be increasing its tree, shrub, and grass components at the expense of forbs, although the shrub component is suspect. This same trend appears in the diversity components for this replication. Based on the one year duration of the study it would be presumptious to claim that the litter component would increase in all years at this rate. There is some reason to believe that the amount of litter that accumulated is a result of a decreased rate in the decomposition process. This reduced rate would have

resulted from the general lack of moisture during the experiment, and the unusually cold winter (Chapter 3).

While there was no correlation of production with percent canopy cover, a good r^2 resulted between production and soil P content by replications. When percent canopy cover was added, through the use of a multiple regression equation, the r^2 was slightly higher than if soil P was the only variable. This general lack of correlation with percent canopy cover would argue for one or two possible explanations. One, light is not the limiting factor on these sites. Halls (1955), working at the Alapaha Experimental Range in Georgia, notes a 70% decrease in grass production when canopy cover reached 40% and remained more or less constant as percent cover increased beyond 40%. From the data gathered at the site there is no way of knowing how much grass is capable of being produced under a zero canopy condition. This leads to the second possibility, that the area is in that portion (40% and greater canopy cover) where the grass component remains more or less constant, i.e. those species that are light limited are absent from the site, or are present in such small quantities as to not influence the results. However, the high variability associated with the understory production at the 40% plus canopy cover at this site does not fit with Halls (1955) model. Production data for this experiment is suspect (discussed later) and this (experimental error) could be the reason for the high variability. As has been noted repeatedly throughout this investigation, the Florida flatwoods are unique and to transfer data or models developed elsewhere can lead to misinterpretations of local conditions. This is not to argue that the canopy cover model does not apply in flatwoods site, but only that the response of production is not smooth. The actual curve is strongly believed to be irregular (noisy) as various environmental factors interact resulting in different combinations becoming

the major limiting factor(s), different from site to site and changing over time.

No aspect of this experiment is more dependent upon accurate sampling procedures than the determination of production. The appropriate number of samples to take in an experiment is dependent upon the variability present in the experiment (Shaw et al., 1976). If the variability is not known beforehand, then preliminary trials should be run in order to determine it. This experiment had high variability as might be expected from a native flatwoods ecosystem. For example, the litter component, which was represented by eight samples for each collection per pasture, had an average CV for the entire experiment of 54%, with highs reaching 95%. The variation for the other species were similar in magnitude.

The experiment started with eight clipped plots per sampling date, reduced to four in November 1976, and raised to eight again in June 1977; not in time to affect the final measurements of the four- and six-month rest treatments. Consequently, the initial and final measurements were made under different sampling modes. Eight clipped plots appear to be too few to account for the variability present in the experiment, four definitely are.

Grazing did not initiate on the same date for all pastures, even within the same treatment nor did they conclude together. Twenty-two head of cattle are needed to graze all pastures in a treatment simultaneously, under the criterion of 50% removal of digestible forage; however, only eleven head were used. Thus, some replications were allowed to have a longer period of growth between grazing applications than others. Also, the date samples were collected after grazing were variable, as short as one and as long as sixty days (replication III, four-month rest). This was the extreme, and aside from winter collections, most sampling was accomplished within twenty days after cattle

entry into the pasture. The fact that these longer delays occurred in the unusually cold winter period does mitigate the effects somewhat, but just how much, is unknown. Caged plots should be used if the grazing time exceeds six days (Mott, 1973).

At least eight people were involved in herbage sampling during the course of the experiment. While all had some familiarity with range plants, there is reason to believe that not all were equally capable of properly identifying the many species that were present on the site. Some species data are highly suspect, especially for legumes. In particular the genera of Galactia, Centrosema, Desmodium, and Clitoria. There is considerable variation within species of these genera, and they are especially difficult to identify when only the vegetative portion is present. Consequently, different workers placed different species into the miscellaneous group for legumes, forbs, grasses, etc. It is believed that species that were identified were reasonably accurate since there was a check made at the time of weighing. However, the actual amount present (biomass) is suspected to be on the low side because of the inclusion into the miscellaneous category. For this reason functional groups (forbs, grasses, etc.) were used to evaluate the results.

The manner in which the herbage meter was used is also suspect. In arid environments water does not constitute a large variable for capacitance type devices as in wetter environments. In Florida, high humidity is the norm, with heavy dews at night and frequent rains. Sampling generally occurred after 10 a.m. in an effort to allow the dew to evaporate before readings were taken, but not always. The meter was calibrated to bare ground before each pasture was monitored. The amount of moisture in the air over bare ground is not the same as that found in the area where there are plants (Rosenberg, 1974). Also dew trapping in plant parts is not accounted for by this procedure for

calibration. The regression equations used for the capacitance meter were based on dry weight determination made in the laboratory after the samples had been dried at 70°C. A better procedure, which would account for higher moisture content in the plants would have been to use double sampling, with wet weights. A multiple regression equation could have then been developed. It is believed that this would yield more accurate results by accounting for variable water content as dew evaporates.

In addition, permanent quadrats were never clipped during the course of the experiment. While the plots to be clipped were selected in a semi-random manner, the quadrats were not randomly placed, being equi-distant on the four lines and each line equal distances apart. The selection of an area similar in composition with the same meter reading as the permanent quadrat could also cause problems although by comparison with the other effects noted, they would seem to be minor.

The growth habit of vines are such that most occur on trees or shrubs, particularly *Smilax spp.* These areas were not adequately sampled. Fire lanes were around most of the pastures, and there were also abandoned roads present (Chapter 3); these areas were not sampled. This definitely biased the species distribution, since these areas contained a high proportion of *P. notatum*, *C. nictitans*, as well as *Rubus spp.* due to high degrees of disturbance. This accounts for the high proportion of these species found in the cattle diets (Chapter 10) but not in the frequency analysis.

Shrubs are not adequately represented due to the few samples taken and the natural hesitation of the field workers to take readings in a large clump of *S. repens*. The inability of the meter to take accurate readings of large shrubs (physical size limitations of the meter) also affected the results of this component. This resulted in various shrubs not being represented in some sampling periods even though the pasture contained a high proportion of them.

The four line transects per pasture that were used in the diversity portion were also not random in that they were set out in equal distances from each other and failed to take account of edge effects. The 30 m line transects were randomly placed using random numbers for the starting point and direction, however, there were no replications within pastures. The use of leaf hits is not the best method to estimate plant frequency as one plant may have numerous shoots or leaves that cross the line in one interval. The use of intervals tends to favor the larger species; one large species could be recorded as hitting several intervals, while several individual small species all hitting in the same interval would only be counted once. Basal hits overcome these problems and are more accurate (NAS, 1962).

The use of intervals with line intercepts transect to obtain diversity indices has not been attempted by other workers, insofar as this investigator is aware. This stems from the limitations mentioned above. However, since the data was available (it was collected by other workers for use in a different study), it was felt that it might, with proper allowances, show up trends in community changes.

Hindsight is often confused with foresight. Should the opportunity arise to repeat this experiment, the following methods should be adopted. The experiment should commence on the same data and end the same way, utilizing sufficient numbers of cattle to graze the treatments simultaneously. Sampling should be conducted immediately after the cattle leave the pasture. Six days should be the maximum grazing period. If this is not feasible then caged plots should be used (Mott, 1973). The number of field workers should be reduced, the same persons used throughout the course of the experiment for all measurements. Soil sampling should be conducted prior to setting up the design of the experiment. Preliminary sampling should be conducted so as to determine the degree

of variability and the numbers of samples collected adjusted according to procedures as in Cochran and Cox (1957) or one of the newer methods such as described by Geng and Hills (1978). The experimental design should be changed from a randomized complete block design to a Latin square; if more pastures were available some sort of factorial or response surface design might be appropriate. The pastures should also be increased in size. Initiation dates should be such that all grazed pastures receive a treatment during the actively growing portion of the year. A normal year should be chosen; failing this, the experiment should run five years to account for climatic variations. Sampling should be random within each pasture. The use of the herbage meter is questionable, but if used, data should be related to the wet weight, with care taken to avoid taking measurements when excess moisture is present.

The above suggestions would lead to the accumulation of valuable information as to what length of rest is best suited for this range flatwoods type habitat, as well as providing some pertinent information involving community interactions.

All of the above factors combine to make the results of this chapter questionable. A notable example is the greater amount of forage present after cattle grazing than before grazing (Figure 9.1.). The preceeding discussion of results is probablistic and emphasis was placed more on apparent trends rather than on hard statistics, since these statistics could be made to demonstrate almost anything, depending upon how the pastures were grouped.

CHAPTER 10

HERBIVORES OF THE FLATWOODS

Introduction

There are many factors that interact in natural southeastern ecosystems that effect the quality and quantity of the resident white-tailed deer (Ococoileus virginianus) populations. Deer are ruminant herbivores that depend directly upon the amount and nutritive value of the plants upon which they feed. These plants, in turn, are dependent upon soil fertility, moisture, available light, climate, level of herbivory, and a host of other factors relating to the dynamics of plant communities.

Quantity of deer foods is not often the limiting factor, except in those instances where overpopulation of the deer herd causes severe range deterioration. In these cases the most preferred and nutritious foods are eliminated first, followed by the less desirable foods (Leopold et al., 1947). When this happens mass mortality of the herd occurs (Christian et al., 1960), usually before any plants have been eliminated from the range (Lay, 1956).

Numerous early investigators have determined the energy requirements (quantity) for deer. For example, Nicol (1936) determined the basal ration for deer and found that 2.2 pounds (1 Kg) of a concentrated ration (alfalfa hay, oats, shelled corn, and rolled barley) per day per hundred weight was necessary for maintenance and growth. Later investigators such as Short (1972) have refined the maintenance and growth requirements for does, bucks, and fawns as a function of age.

Concomitant to the realization that deer have certain basic energy requirements, studies were begun on the observed fact that deer prefer different

foods at different times of the year (Maynard et al., cited in Hundley, 1956). Investigations using grazing trials, observations of tame deer, rumen contents, etc., have resulted in extensive lists of preferred deer foods, usually broken down as to seasons (Harlow and Hooper, 1971; Harlow and Jones, 1965; Short, 1971). Deer foods have also been categorized into more general groupings. Moore and Manney (1962) have listed foods for white-tailed deer on the Piedmont of Georgia, into four classes: Preferred (candy species); staple (foundation diet); emergency (life sustaining); and stuffing (starvation).

The observation that on good range, deer gain weight quicker, weigh more as adults, bear more young, have greater vitality and larger antlers than do deer on poor ranges (Williams, 1972) has led to a redirection of emphasis toward forage quality. Quality of the diet is now known to be more important than the quantity consumed (Lay, 1964). When an area is evaluated solely on the basis of available dry matter, as it often is, capacity is generally overstated (Blair et al., 1977).

Much of what has been mentioned for deer apply equally well for cattle. Cattle are primarily grazers, where deer are browsers. The major reason for this difference is the construction of the mouth parts. Deer, like sheep, have both upper and lower incisors and grasp the plant between their teeth to tear off each mouthful. Cattle have no upper incisors and use their highly mobile tongue as prehensile organs. The tongue encircles the plant and draws it into the mouth where a pinching action of the tongue and lower teeth bind the plant so that it can be torn off. The structure of the lower jaw makes it impossible for cattle to graze closer than 1.2 cm while sheep and deer can graze virtually at soil level (Hafez et al., 1969).

Cattle, because of the numbers involved, affect the range differently than do deer. Trampling losses range from 1% on lightly grazed ranges, to 5% on

heavily grazed pastures (Quinn and Hervey, 1970). Defecation is suspected of reducing usable forage yield by some (Petersen et al., 1956a), although MacDiarmid and Watkin (1972) suggest otherwise. Bedgrounds, mineral and salt licks, and water holes may be denuded of vegetation (Heady, 1975). Overuse of a range will also lower carrying capacity, by causing an invasion of less preferred species (Merrill, 1959).

Soil compaction, due to grazing, has been studied and the effects on soils and plant cover reported (McCarty and Mazurak, 1976; Orr, 1975). Depth of compaction seldom reaches 15 cm and usually is limited to the top 5 cm, and is directly related to intensity of grazing (Reed and Petersen, 1961; Read, 1957; Brown and Schuster, 1969). Recovery varies from three to ten years after cessation of heavy use (Orr, 1975; Reynolds and Packer, 1963; Lusby, 1970).

Forage quality is more than percent digestibility. Studies at the University of Florida have demonstrated that considerations of digestibilities alone, without a measure of forage intake, are relatively meaningless (Abrams et al., 1978). Unless it is known how much of a particular plant is eaten, digestibility becomes of use only as a relative quality index.

Energy relationships of feeds to animals are generally expressed as calories of energy (eq. 6). The energy content of a feed before intake is the feed energy. After the energy contained in the feces is removed the balance is digestible energy (DE). Metabolizable energy (ME) is DE less the energy contained in the urine and various gasses (methane) and net energy (NE) is ME after the body heat increment is removed (Mott, 1973). NE is that energy used by the animal for growth, lactation, and reproduction. Various conversion factors from one form of energy to another exist and may be found in Maynard and Loosli (1969), NAS (1976).

Some criteria necessary in the evaluation of forage quality are DE and protein content of the feed. The term, crude protein (total nitrogen content multiplied by 6.25), has been used in the past to qualify feeds. However, since animals vary considerably as to specific amino acid requirements the term protein, is to be preferred (Maynard and Loosli, 1969). Most ruminants require an average protein content of about 7% (e.g. cattle) although the actual amount varies considerably during different periods of growth (Maynard and Loosli, 1969; NAS, 1976). Harlow and Jones (1965) have stated that deer may require average protein intakes of about 10%. The protein content of cattle and deer foods have been found to vary greatly between species and also within the same species at different seasons. This is also true for digestibility and chemical content of plants (Thorsland, 1966; Moore, 1973; Blair and Epps, 1969; Harlow and Jones, 1965; Hundley, 1956).

Other important nutrients are phosphorus and calcium, McEwen (1957) has stated that Ca levels in browse plants of 0.64% and P levels of 0.56 are necessary for maintaining healthy deer. A mature dry 400 Kg cow requires a minimum of 11 g per day of P and Ca (NAS, 1976). In general, adequate Ca and P nutrition is dependent upon three things: 1) a sufficient supply of each; 2) a suitable ratio between them; and 3) the presence of vitamin D. A desirable Ca:P ratio has been defined as one lying between 2:1 and 1:1; however, it is possible to have adequate nutrition outside of these limits (Maynard and Loosli, 1969).

It has been noted that animals select forages higher in crude protein and digestibilities than were observed in the available forage sample (Coleman and Barth, 1972). This ability would imply a higher carrying capacity than would be recommended, based on sampling procedures. However, since the most nutritious portions of a plant are generally the young growing portions, continual removal of these parts could seriously affect the plant and bring

about range deterioration. Hence, the need to define the forage quality of an area accurately and adjust the stocking rate accordingly.

Cattle and deer forage in the Southeastern Coastal Plains is generally not considered to be deficient in energy, except during severe and prolonged winters. However, the protein and P content of these plants are often deficient (Murphy and Coates, 1966; Blair et al., 1977; Hundley, 1956). Florida, aside from lying in the Coastal Plain, has approximately one half of its total area composed of soils that are loosly grouped as flatwoods (White and Pritchett, 1970). These soils, mostly Spodosols, are acid sand to loamy sands and are extremely low in nutrient content (Chapter 3).

There has been, and perhaps always will be, some concern by wildlife people and cattlemen that deer and cattle compete with one another for the available food resource. Studies have not borne out this contention to any great degree (Stoddart and Smith, 1955; Heady, 1975). In fact, Anthony and Smith (1977) found that there was considerably less diet overlap on a range in Southeastern Arizona between a herd of Mule deer (Odocoileus hemionus crooki) and a herd of white-tailed deer than might be expected. A study investigating the interactions of mule deer, elk, and cattle in Montana, indicated a high rate of competition between elk and cattle and virtually no competition between deer and cattle (Mackie, 1970).

Different species of animals have different food requirements and while they may appear to be eating the same thing, they seldom are (Harris, 1972; Bell, 1971; Lamprey, 1963). For example, contrary to some, Florida deer do not consume twigs as they are believed to do in the north. Most food taken by them occurs close to the ground, which makes it appear that they are grazing (Williams, 1972). Some grasses are eaten, but generally only during the new growth cycle of the grass, and then not in significant amounts, less than 2% of the winter diet (Harlow and Jones, 1965).

The concept of multiple use implies that an area is used for more than one purpose. In the case of Florida rangelands this usually means some combination of timber, wildlife, and cattle. Mieland (1945) has long championed the cause of multiple use in Florida, yet there are few definitive studies on the effects of different animals utilizing the same area. Cook (1954), in Utah, recommends the common use of summer range by cattle and sheep after a diet analysis. In Texas, the use of the multiple animal concept (cattle, sheep, goats, deer) has been shown to be more economical than single unit enterprises. When these areas are properly managed, the range is maintained in top condition (Merrill and Young, 1952; Merrill et al., 1966). The reaction of the local deer herd to these practices was found to be minimal (Merrill et al., 1957).

Forage quality is seen to be an interactive effect of a variety of different factors. Any one such factor can only give a relative measure of quality. However, because of the many difficulties of multifactored investigations (time, money, facilities, etc.), experiments involving only a few of these factors will continue to play an important role in delineating forage requirements for the successful management of cattle and deer in Florida.

The role of insects in rangelands is an area that until recently has been ignored (Hewitt et al., 1974). Many ecologists still consider that herbivore consumption in a natural ecosystem is negligible (Petrusewicz and Grodzinsky, 1975). Only when numbers rise to epidemic proportions was much attention given to the role of insects. Early works, notably Wolcott (1937) in Northern New York reported that the biomass of insects present and the amount of forage eaten was larger than the biomass of cattle that were on the pasture and the amount of forage they consumed. In New Zealand, Given (1966) reported that pasture grubs often have a larger biomass than the sheep that were grazing there. A recent study by Bowers and Haws (1978), on a Utah range indicated that the

insects were consuming 2.8 animal unit months (AUM) while the cattle consumed 2.1 AUMs on the same study site. No comparable study is known to exist for Florida ranges.

The functional role of the herbivore in a grazing system can take many forms depending upon the species and how and when grazed. The Colorado beetle consumes 20% of the potato plant leaves, but the yield is decreased only one or two percent (Petrusewicz and Grodzinski, 1975). The other extreme is the study by Varley (1967), which showed that the biomass loss in wood increment of oaks was many times greater than the foliage biomass consumed by caterpillars. Herbivory also stimulates production (Petrusewicz and Grodzinski, 1975; Heady, 1975; Moore, 1966), and has been linked as a regulator of forest primary production (Mattson and Addy, 1975). Herbivory also acts to increase the turnover rate of nutrients, by increasing the rate of decomposition through digestion, burying material in underground caches, trampling standing material so that it is in contact with the soil, and frass (Grant and French, 1975; Heady, 1975; Petrusewicz and Grodzinski, 1975). The activity of the Scarabaeidae (dung beetles) has been reported from ancient times, mostly because of its curious habit of rolling balls of dung and burying them (Sharp, 1970). The dung beetles importance in pasture fertility has been noted particularly in Australia (Bornemissza, 1960; Gillard, 1967).

This study, utilizing data obtained from analysis of forage plants present on a flatwoods site (Chapters 7 and 8), attempts to define quality of this site in terms of the nutritional requirements of cattle. This is accomplished through bite-count analysis of the grazing cattle and estimated intakes of the various species. Since species that represent the bulk of the deer diet were not adequately sampled, this type of analysis was not made for deer. Effects of insects, primarily ground crawling insects, was initiated to gain

a measure of information as to the kinds and numbers present for one point in time. Cattle grazing effects on insect numbers and kinds was also investigated.

Materials and Methods

Bite count and diet determinations of the various species at the BRU were obtained from Gumma (1977) for the summer, fall, and winter of 1976. Bite count data was obtained for spring 1978 from unpublished data (Springer, 1978)[9]. The minimal daily intake as given by the National Research Council (NAS, 1976) for a 400 Kg cow of average milking ability, over the course of a year (weaning the calf at six months of age), was multiplied by the percent of each specie consumed, determined. Cattle were assumed to all calve on 21 March and weaning occurred on 21 September for this analysis.

Equation 6 was used to determine the amount of digestible energy intake required per day per specie. The value for all species utilized were then summed. This value was multiplied by 0.8 (NAS, 1976) to obtain ME, which are the units used in the NAS tables. Values for percent organic matter and digestibilities were taken from the studies in Chapter 7 and nutrient content from Chapter 8. All digestibility and mineral data were grouped into four, three-month seasons. Seasonal variations of protein were estimated based on known variations and the data given in Chapter 7. Total protein content of the species ingested by the animal was calculated and compared to total protein required (NAS, 1976). Mineral content was determined based on the amount of material ingested and the percent of P and Ca present in that sample (Chapter 8).

Cattle were weighed as they went into each pasture and again when they came off. Cattle were not assigned to a particular group, and no particular group was assigned to a definite sequence of pastures. Individual weight records were kept for each animal.

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9. Springer, T. 1978. Range student, Univ. Fla., unpublished data.

When the cattle were not on the site they were kept in a nearby bahiagrass holding pasture. All animals on the holding pasture were fed molasses (32% protein) and hay from 23 November 1976 to 18 February 1977. Range pellets were fed all animals regardless of location from 17 January 1977 to 4 May 1977. Mineral mix was available at all times.

Fecal output was estimated per pasture by three 100 m transects, 3 m wide. These belt transects were employed after the cattle had left the pasture. All cow pies which were believed to have been deposited in the last grazing period were counted. The total number of pies per pasture was obtained by a ratio to the known pasture size. This determination was made for all pastures, after each grazing treatment. To obtain the weight of the cow pies, 10% of the number of the pies reported in the transect were randomly selected from the pasture and dry weights obtained. The equation for estimating indigestibility of forage by measuring fecal output and forage consumed (described by Morris and Kovner, 1970; Mott, 1973), was modified (eq. 7) to give the amount of feed intake per grazing period per pasture.

Determination of an overall weighted digestibility was calculated using the bite count data of Gumma (1977) and Springer[9] as the percentage of the diet. This value was multiplied by the percent IVOMD for that species and summing for each season. The above method of determining average digestibilities was patterned after Pearson (1967a).

The number of cattle that were in the pasture and the number of days the pasture was grazed were multiplied together to give total cow days per pasture for each grazing treatment. Two comparisons were made; the amount of forage estimated to have been removed by the regression equations with the herbage meter (Chapter 9) and the forage intake calculated from equation 7. Both of the estimations of forage comsumption were divided by the number of cow days and an average intake per cow per day determined.

The arthropod study commenced on 25 September and concluded on 1 October 1977. Pitfall traps, as modified by Smith (1976), were used to sample the arthropod population. Two pitfall designs were used in this investigation; one design was open to all directions (+ trap) and the other was open 90° (V trap). Six traps, two +'s and four V's were used in all pastures in replication I. The traps were set out in a north-south line dividing each pasture. The V traps were set up on this line 1.37 m apart, each V trap facing a cardinal direction of the compass. The + traps were set at each end of the V traps, 13.7 m from the V traps. All other replications had + traps only, placed 13.7 m from the center of the pasture in a north-south direction.

Water was placed in the traps to a depth of about 3 cm. The traps were collected every afternoon, starting at 4 p.m. The arthropods were placed in alcohol and identified as to family or group (class or order) the next morning. Identification was based on the method of Jaques (1947) with additional information from Ross (1965), Sharp (1970), and Levi and Levi (1968). Data was collected for five days.

The arthropods were grouped into different classifications (classes, orders, and families) for ease of analysis, with total numbers, total number less the ants and chiggers, individuals in a grouping, and number of families, used for the basis of statistical comparisons. A randomized complete block design, ANOVA, and a t-test were used to determine effects.

Two collections were made prior to filling the traps with water. Members of the family Lycosidae of the class Arachnida (wolf spiders) and the families Carabidae (ground beetles) and Gryllidae (crickets), of the class, Insecta, were marked with nail polish and released. A ratio of the number marked to the number re-captured to the total population caught, gives an estimate as to the total population of the group.

After identification, the insects were dried for three days at 70°C, and weighed and individual weights determined. Samples of crickets, spiders, and beetles were ground (1 mm mesh screen) and subjected to chemical analysis for P, Ca, and K with the same procedures as for foliar analysis (Chapter 3).

Results

Digestible energy (DE), protein, P, and Ca were computed based on bite count data for the different species. The total amount of the above parameters were determined for each of the four seasons (Table 10.1.). The average digestibilities of the diet was found to cycle with the seasons, with the low (23.1%) occurring in the fall; winter was 24.6% and spring and summer were 28.1 and 31.9%, respectively. Of interest is the high proportion of _H. graminifolia_ (grassyleaf golden aster) that comprises the diet, from a low of 5.5% in the fall to a high of 26.4% in the summer. _S. repens_ (saw palmetto) is a major contributor in the winter (31.3%); _Q. incana_ (water oak) in the spring (26.4%); and _A. stricta_ (wiregrass) in the fall (31.7%).

The sample diet is not meeting the basic nutrient requirements for a 400 Kg cow as given by National Research Council (NAS, 1976). Energy (DE) is the major factor, although total protein and P are also below minimums. Calcium intake was the only nutrient that was above minimal levels, although the Ca:P ratio was out of balance, holding fairly close to 5:1 for all seasons.

The dates the cattle entered the study site, and the dates they were removed, with individual cattle weights are presented in Appendix F, Table F.1. Relative percent changes, from the weight at site entry to weight at site exit, are summerized in Table 10.2. Generally, all cattle lost weight when placed on the site (Table 10.2.). Cow #248 indicated the best performance losing weight only three of the nine times she was on the site. The steer was, with a single exception, a consistent loser, having a weight loss ten of

Table 10.1. Forage quality of range diet based on bite counts for different seasons.

Species[9]	Diet[1] %	Wt.[2] Kg	OM[3] %	Dig.[4] %	DE[5] MCal	Protein[6] g	P[7] g	Ca[7] g
				Winter				
Andropogon virginicus	3.9	.293	91	21.1	.247	8.5	0.2	0.3
Aristida stricta	21.4	1.605	92	13.3	.864	48.2	1.0	2.2
Callicarpa americana	-	-	-	-	-	-	-	-
Cassia nictitans	-	-	-	-	-	-	-	-
Centella asiatica	3.0	.225	84	13.9	.116	14.6	0.2	0.6
Centrosema spp.	-	-	-	-	-	-	-	-
Ctenium aromaticum	-	-	-	-	-	-	-	-
Erograstis spectabilis	0.3	.023	88	24.7	.022	1.0	0	0
Galactia spp.	-	-	-	-	-	-	-	-
Heterothecia graminifolia	15.5	1.163	89	40.7	1.853	80.2	1.1	9.6
Ilex glabra	-	-	-	-	-	-	-	-
Panicum anceps	1.5	.113	85	39.1	.165	5.7	0.2	0.7
Paspalum notatum	5.1	.383	85	36.9	.528	9.6	0.7	1.0
Quercus incana	4.5	.338	91	22.8	.308	22.3	0.3	3.7
Quercus pumila	1.5	.113	90	17.6	.078	7.3	0.2	1.2
Rubus spp.	8.2	.615	89	25.6	.617	30.8	0.6	2.8
Schyizachyrium stolonifer	0.8	.060	90	27.3	.065	2.2	0.1	0.2
Serenoa repens	31.3	2.348	89	23.6	2.170	117.4	1.6	3.8
Smilax auriculata	1.3	.098	93	27.9	.111	5.5	0.1	0.9
Sorghastrum nutans	0.7	.053	89	17.7	.036	1.6	0	0.1
Sporobolus curtissii	0.7	.053	91	21.5	.050	1.7	0	0.1
Tephrosia spp.	-	-	-	-	-	-	-	-
Vaccinium myrsinites	0.3	.023	92	26.6	.024	0.6	0	0.2
Total in diet	100.0	7.500	-	24.6	7.248	357.2	6.3	27.4
Required for a 400 Kg dry cow (last half postpartum)[8]	-	7.500	-	-	17.875	440.0	14.0	14.0

1. Base on bite count (Gumma, 1977)
2. Percent of NRC minimum intake
3. Percent organic matter of species
4. Percent *in vitro* digestibility, weighted average.
5. DE from eq. 1
6. Total protein in diet sample
7. Amount in diet sample
8. NRC (1976) value for ME/0.8
9. All species italicized.

Table 10.1. - continued

Species[9]	Diet[1] %	Wt.[2] Kg	OM[3] %	Dig.[4] %	DE[5] MCal	Protein[6] g	P[7] g	Ca[7] g
				Spring				
Andropogon virginicus	0.6	.053	91	26.5	.056	2.7	0.1	0.1
Aristida stricta	10.9	.959	92	15.5	.602	32.6	0.6	1.5
Callicarpa americana	-	-	-	-	-	-	-	-
Cassia nictitans	0.3	.026	90	28.2	.030	3.8	0.1	0.2
Centella asiatica	-	-	-	-	-	-	-	-
Centrosema spp.	-	-	-	-	-	-	-	-
Ctenium aromaticum	0.7	.062	90	24.5	.060	5.1	0.1	0.2
Erograstis spectabilis	0.8	.070	88	31.5	85.900	5.6	0.1	0.2
Galactia spp.	0.5	.044	90	41.2	.072	6.1	0.1	0.4
Heterothecia graminifolia	14.7	1.294	89	41.2	2.087	91.8	1.7	12.7
Ilex glabra	-	-	-	-	-	-	-	-
Panicum anceps	3.2	.282	85	54.7	.576	19.4	0.3	1.1
Paspalum notatum	4.3	.378	85	57.5	.814	16.3	1.1	1.4
Quercus incana	26.4	2.323	91	21.9	2.037	220.7	2.7	15.9
Quercus pumila	8.5	.748	90	18.4	.545	50.9	1.3	7.3
Rubus spp.	-	-	-	-	-	-	-	-
Schyizachyrium stolonifer	1.2	.106	90	34.2	.143	7.5	0.1	0.4
Serenoa repens	16.7	1.470	89	22.0	1.266	101.4	1.1	4.0
Smilax auriculata	4.3	.378	93	33.2	.514	26.1	0.3	1.7
Sorghastrum nutans	1.0	.088	89	26.9	.093	3.3	0.1	0.5
Sporobolus curtissii	0.8	.070	91	18.8	.053	2.5	0	0.1
Tephrosia spp.	0.6	.053	89	40.9	.085	6.6	0.1	0.5
Vaccinium myrsinites	4.5	.396	92	39.0	.625	20.2	0.3	1.8
Total in diet	100.0	8.800	-	28.1	9.742	622.6	10.2	50.0
Required for 400 Kg wet cow (Avg. milking ability)[8]	-	8.800	-	-	21.250	810.0	25.0	25.0

Table 10.1. - continued

	Summer							
Species[9]	Diet[1] %	Wt.[2] Kg	OM[3] %	Dig.[4] %	DE[5] MCal	Protein[6] g	P[7] g	Ca[7] g
Andropogon virginicus	6.2	.546	91	15.4	.337	23.5	0.7	2.4
Aristida stricta	2.6	.229	92	17.6	.163	7.6	0.2	0.3
Callicarpa americana	2.4	.211	87	35.4	.285	22.6	0.4	1.5
Cassia nictitans	5.4	.475	90	19.3	.363	60.7	0.7	2.8
Centella asiatica	0.4	.035	84	30.1	.039	4.0	0.1	0.5
Centrosema spp.	6.2	.546	88	38.9	.822	63.8	0.8	5.5
Ctenium aromaticum	0.8	.070	90	25.1	.070	5.0	0.1	0.2
Erograstis spectabilis	0.9	.079	88	38.7	.119	9.1	0.1	0.2
Galactia spp.	13.9	1.223	90	34.1	1.652	117.4	1.5	10.6
Heterothecia graminifolia	26.4	2.323	89	36.0	3.275	141.7	2.6	18.2
Ilex glabra	1.0	.088	91	34.6	.122	3.4	0.1	0.6
Panicum anceps	4.2	.370	85	51.1	.706	22.5	0.5	1.8
Paspalum notatum	4.5	.396	85	48.6	.720	28.5	1.1	1.4
Quercus incana	4.0	.352	91	22.9	.323	27.5	0.4	2.9
Quercus pumila	0.6	.053	90	20.9	.044	3.9	0.1	0.4
Rubus spp.	-	-	-	-	-	-	-	-
Schyizachyrium stolonifer	0.7	.062	90	31.6	.077	2.6	0.1	0.2
Serenoa repens	7.0	.616	89	18.3	.441	43.7	0.5	1.0
Smilax auriculata	5.8	.510	93	30.2	.631	30.6	0.4	3.8
Sorghastrum nutans	1.5	.132	89	34.6	.179	4.5	0.1	0.5
Sporobolus curtissii	0.7	.062	91	26.4	.065	2.2	0.1	0.2
Tephrosia spp.	3.3	.290	89	32.1	.365	38.0	0.4	2.1
Vaccinium myrsinites	1.5	.132	92	33.9	.181	5.3	0.1	0.7
Total in diet	100.0	8.800	-	31.9	10.979	668.2	11.1	57.8
Required for 400 Kgwet cow (Avg. milking ability)[8]	-	8.800	-	-	21.250	810.0	25.0	25.0

Table 10.1.- continued

Species[9]	Diet[1] %	Wt.[2] Kg	OM[3] %	Dig.[4] %	DE[5] MCal	Protein[6] g	P[7] g	Ca[7] g
				Fall				
Andropogon virginicus	0.4	.024	91	24.5	.024	0.9	0	0
Aristida stricta	31.7	1.934	92	15.2	1.190	61.9	1.4	3.1
Callicarpa americana	-	-	-	-	-	-	-	-
Cassia nictitans	14.0	.854	90	22.6	.764	55.5	1.0	5.6
Centella asiatica	0.8	.049	84	39.7	.072	4.6	0.1	0.6
Centrosema spp.	0.5	.031	88	36.9	.044	1.7	0	0.3
Ctenium aromaticum	0.3	.018	90	23.5	.017	1.2	0	0
Erograstis spectabilis	0.3	.018	88	30.9	.022	1.2	0	0.1
Galactia spp.	0.9	.055	90	27.1	.059	2.0	0.1	0.6
Heterothecia graminifolia	5.5	.336	89	34.2	4.493	20.8	0.4	3.0
Ilex glabra	0.8	.049	91	39.6	.077	1.5	0	0.4
Panicum anceps	1.0	.061	85	38.1	.087	3.5	0	0
Paspalum notatum	9.2	.561	85	44.2	.928	24.1	1.4	2.0
Quercus incana	6.0	.366	91	22.3	.327	26.4	0.3	3.5
Quercus pumila	1.5	.092	90	19.1	.069	6.5	0.1	0.9
Rubus spp.	-	-	-	-	-	-	-	-
Schyizachyrium stolonifer	0.2	.012	90	30.1	.015	0.5	0	0
Serenoa repens	18.9	1.153	89	16.6	.749	60.0	1.1	2.2
Smilax auriculata	5.1	.311	93	34.4	.438	17.7	0.3	2.5
Sorghastrum nutans	0.8	.049	89	19.5	.037	1.6	0	0.2
Sporobolus curtissii	-	-	-	-	-	-	-	-
Tephrosia spp.	1.1	.067	89	35.8	.094	7.0	0.1	0.8
Vaccinium myrsinites	1.0	.061	92	31.7	.078	2.0	0	0.3
Total in diet	100.0	6.100	-	23.1	5.540	300.6	6.3	32.4
Required for 400 Kg dry cow (first half postpartum)[8]	-	6.100	-	-	14.875	360.0	11.0	11.0

Table 10.2. Relative percent change in individual cattle weights from date of entry to the site, to date of leaving.

Date in	Date out	Cattle #6[1]	#122	#134	#135	#248[2]	#295	#362	#371	Steer	Calf
7/12/76	7/30/76	1.4	-2.6	4.2	0.6	1.2	1.2	4.9	-2.3	1.4	-
8/7/76	8/27/76	-4.0	-5.8	-8.7	-4.1	-7.6	-3.0	-3.9	-5.5	-5.9	-
9/14/76	9/29/76	0.7	-2.5	-10.4	-7.7	1.1	3.9	-6.9	-3.8	-7.3	-
11/9/76	11/13/76	-	5.1	9.8	3.0	3.3	1.1	3.1	1.5	-1.1	-
12/9/76	12/14/76	-6.3	-7.6	-6.5	-3.6	0	-5.6	-4.5	-4.7	-8.2	-
1/14/77	1/18/77	-2.7	2.0	-5.8	-1.9	-	-4.8	-10.0	-	-7.1	-
2/14/77	2/18/77	2.8	-1.3	-	-3.6	-	-2.5	-	-	-3.2	-
4/12/77	4/24/77	-12.6	-8.4	-5.8	-9.0	-4.4	-7.1	-13.2	-1.3	-6.9	-
6/17/77	6/25/77	1.6	0.6	-3.9	-4.2	-4.7	-4.1	-2.5	0.7	-9.1	-5.0
7/12/77	7/27/77	-2.3	-2.8	-5.1	-3.8	3.2	-1.6	-2.6	-8.6	-13.3	2.5
8/19/77	9/16/77	-10.1	-4.6	0.7	7.0	3.2	-5.3	-7.5	-3.4	-4.4	4.5

1. Cow #6 calved 2/20/77, 25 Kg bull calf.
2. Cow #248, stillborn calf, 1/25/77.

the eleven times on the site. The other animals showed a weight increase two or three times out of the possible eleven grazing periods.

The calculations of forage intake for the two-month rest treatments for the July and August grazing periods from Appendix A, Table A.1. and from equation 7, (fecal output and average digestibility) are presented in Table 10.3. The amount of dry matter consumed per animal per day (calculated from the fecal output data) is low compared to minimal dry matter requirements obtained from NAS (1976). The values computed from Appendix A, Table A.1. are more reasonable except for replication I, where the regression equations indicated more herbage present after grazing the pasture than before grazing.

A sample diet for deer at the Ocala Wildlife Management Area, for late fall and early winter is presented in Table 10.4. Over 51% of the diet is composed of species that were not covered by this study. Consequently, no comparable diet quality analysis was attempted for deer, as was made for cattle.

There were a total of 4317 arthropods captured during the collection period. Of this number 80% were either Formicidae (ants) or Trombiculidae (chiggers). A ranking of the number of arthropods caught for each type group, along with common names, is presented in Table 10.5.

Total arthropod numbers and numbers of families were not found to be different with respect to the different grazing treatments. Of the various families that were analyzed for differences in population levels as a function of the different grazing treatments imposed, only the family Lycosidae (wolf spiders) were found in higher numbers ($P < 0.05$) in the two-month rest pastures than in the ungrazed (Table 10.6.).

The mark and re-capture analysis resulted in 17 wolf spiders, 51 crickets, and 11 beetles marked. There were five spiders and one cricket re-captured.

Table 10.3. Calculations of forage consummed in the 2 month rest pasture (July and August 1977) per cow per day by two different methods; estimations of forage removed (Table A.1) and by eq. 7 (fecal output and average digestibility).

	Replication			
	I	II	III	IV
Cow days	25.00	60.00	40.50	22.50
Forage removed Table 1 Kg	-424.30	570.70	404.10	354.90
Avg. daily consumption per cow (Kg)	-	9.50	10.00	15.40
Fecal matter at end of grazing period (Kg)	30.28	31.81	38.69	36.50
Dm intake[1] per pasture (Kg) (eq. 2)	44.50	46.70	56.80	53.56
Avg. daily consumption per cow (Kg)	1.78	0.78	1.40	2.38

1. Average summer digestibility equal to 33.9% by methods of Pearson (1967a).

Table 10.4. List of food items from stomach analysis of deer collected on Ocala Wildlife Management Area, September - February, 1952 - 1953.

Food item [1]	Part eaten	% Total volume
Sabal etonia	Fruits	31.10
Basidiomycetes	Entire	25.15
Quercus spp.	Acorns	12.51
Serenoa repens	Drupes	8.90
Galactia	Stems - Leaves	1.50
Vaccinium myrsinites	Leaves - Twigs	1.34
Gramineae	Stems - Blades	0.38
Mixed legumes	Leaves - Stems	0.21
Smilax spp.	Leaves - Vine	0.16
Misc.	-	18.75

Note: Adapted from Harlow (1961).

1. All species italicized.

Table 10.5. Number of different groups of Arthropods caught in pit traps September 1977.

Grouping [1]	Common name	# Caught
Formicidae	Ants	2195
Trombiculidae	Chiggers	1280
Lycosidae	Wolf spiders	249
Acarina	Mites	186
Gryllidae	Crickets	174
Arichnids	Misc. spiders	57
Curculionidae	Snout beetles	27
Carabidae	Ground beetles	21
Mutillidae	Velvet ants	17
Scarabaeidae	Dung beetles	17
Chilopoda	Centipedes	14
Melandryidae	Bark beetles	12
Staphylinidae	Rove beetles	12
Tettigoniidae	Camel crickets	10
Acridae	Grasshoppers	7
Opilones	Daddy-longlegs	4
Reduviidae	Assassin bugs	4
Bostrichidae	Power-post beetles	3
Chrysomelidae	Leaf beetles	3
Trogidae	Skin beetles	3
Coccinellidae	Lady bugs	2
Elateridae	Click beetles	2
Lepidoptera	Misc. moths, butterflies	2
Phasmididae	Walking sticks	2
Homoptera	Misc. Leafhoppers, treehoppers, etc.	2
Diptera	Misc. Flies, mosquitoes, etc.	2
Phalacridae	Shining flower beetles	1
Erotylidae	Pleasing fungus beetles	1
Eurytomidae	Straw worms	1
Blattidae	Cockroaches	1
Diplopoda	Millipedes	1
Passalidae	-	1
Tenebrionids	Darkling beetles	1
Ostomatidae	Bark-gnawing beetles	1
Thysanoptera	Thrips	1
Scorpiones	Scorpions	1
Nabidae	Damsel bugs	1
Cydnidae	Burrowing bugs	1
Total		4317

1. All groupings are italicized.

Table 10.6. Average number of Lycosidae caught during the five day collecting period, by pasture.

Grazing treatment (month rest)	Replication I	II	III	IV	$\overline{X}$
2	14.6	14.0	12.1	13.0	13.4
4	24.7	17.6	18.0	10.1	17.6ab
6	19.2	20.0	22.0	18.9	20.1b
12	22.7	19.5	26.0	19.0	21.8b
$\overline{X}$	20.3	17.8	20.3	15.3	

Trt F = 5.398 Blk F = 2.059

This gives population estimates of 847 spiders and 8874 crickets for the areas around the pitfall traps. There was no differences noted for any of the V traps that would indicate any type of movement pattern for any of the different groupings.

Of all the crickets captured, 87% belonged to the species Gryllus ovisopus, the remaining were G. fultoni. Identification to specie was made with the assistance of T. L. Walker[10]. G. ovisopus is a mute, sedentary cricket (Walker, 1973), with males the most mobile, moving about 14 m per night[10]. Chemical analysis for P, Ca, and K and individual weights are presented in Table 10.7. for crickets, spiders, and beetles.

Assuming that the traps were 50% efficient and that the average radius of motion was 14 m, then calculations indicate that there would be about 2×10^5 crickets per pasture (0.8 ha average). Further assuming that the ratio of 1:10 (trophic level conversion) exists for spiders, the primary predators of Gryllus, then there would be 2×10^4 spiders per pasture. This 1:10 ratio is borne out by the results of the mark and recapture data. From data in Table 10.7. there would be about 10 Kg dry weight of these two arthropods present in east pasture. At an 80% moisture content this represents about 50 Kg biomass of these two groups per pasture. The chemical content of this amount is about 0.8, 0.04, and 0.9 Kg of P, Ca, and K, respectively, for each pasture.

Discussion and Conclusions

The emergence of H. graminifolia as a major contributor to range cattle diets was first mentioned by Gumma (1977). Gumma also noted that the selectivity ratio (percent in the diet/percent available) was less than 1.0, which

10. Walker, T. L. 1977. Prof. Dept. Entomology, Univ. Fla., Personal communication.

Table 10.7. Average weight and P, Ca, and K content of three groups of insects trapped at the study site.

	Avg. wt. (g)	P(ppm)	Ca(ppm)	K(ppm)
Beetles	.0328	5840	1360	6630
Crickets	.0300	9370	2430	9420
Spiders	.1501	12250	2470	10200

indicates that the animals were not actively seeking out this species. *H. graminifolia* was also relatively high in digestibility and nutrient content (Chapters 7 and 8). This plant may play a more important role in range cattle diets than has heretofore been suspected and should be researched further.

Serenoa repens, *A. stricta*, and *Q. incana* are also consumed in fairly large quantities (25 - 30%) at different seasons, however they have low digestibilities (20%) and are low in P. It is doubtful that they are preferred foods (Gumma, 1977) but should be considered as emergency, or more likely, stuffing.

With the exception of the first grazing period, the cattle generally lost weight each time they were placed on the site. There are several explanations for this observation. The cattle were being taken from a good pasture with adequate supplements and placed on a poor quality range at irregular intervals. Cattle lose weight when the diet is shifted (Ensminger, 1976), when they are moved (Heady, 1975; Wagonner et al., 1960; Snapp and Newmann, 1960), or almost any time anything is done to them out of the ordinary (Hafez, 1969; Bonsma, 1965), particularly in warm climates (McDowell, 1972; Bonsma, 1965). The process of driving the cattle out of the pasture and weighing them would also cause a weight loss. Differences in the amount of fill would also be a factor for the loss of weight noted. The length of time the animals were on the site was, with two exceptions, not long enough to gain an accurate weight picture of the animal performance. The two longest periods the animals were on the site were the initial and final grazing periods, 18 and 28 days, respectively. In the first period all but two animals showed a net weight gain. In the last grazing period only three did (four, counting the calf, however, his mother showed the greatest weight loss). On the basis of these two observations it would appear that animal selection

is a major factor for a successful range operation. This observation is in agreement with this investigators own practical experience with range animals in Utah and Nevada.

In the study of the comparative digestive efficiencies between Bos taurus (Hereford) and Bos indicus (Brahman) cattle, Howes (1964) found that on a low level of protein intake, Brahman cattle digested more protein and consumed more dry matter than did Herefords. It is strongly suspected that had Brahman or Brahman-crossed cattle been used, cattle performance on the study site would have been improved.

Based on the quality diet determinations and the lackluster performance of the animals, energy would appear to be the main limiting factor. The calculated DE available is in all seasons less than half of the required energy. It is extremely doubtful that the actual diet was this low compared to the minimum maintenance requirement. As mentioned in the introduction, animals appear able to select a higher quality forage than is indicated by sampling techniques. This is further attested to by the relatively low loss of weight the animals experienced on the site, which was about 5%. Weight losses in this range could be explained by other factors, as mentioned above.

Forage intake determinations based on the average digestibility of the forage and the amount of fecal output, did not give values that could be reasonably interpreted as minimal dry forage intake (approximately 2% of body weight). This was found to be generally true for all pastures. The values calculated from the regression equations were, in general, better but still showed considerable variations. For the above reasons, no data for forage intake are presented other than that given in this chapter (Figure 10.3.).

The quality of range foods for cattle and, by analogy, deer in the Florida flatwoods are low. Digestible energy requirements are, in general, not being met for English breed cattle. Deer, being adapted to the general location,

appear to be able to select higher quality foods than domestic cattle. However, the imbalance of the Ca:P ratio (5:1) in flatwoods forages may well be one reason why there are not more deer found in these regions.

Selection of the proper type of cattle to use on a range area would be a fruitful area of research. Tests at the range cattle experiment station in Florida on native range showed that crossbred Brahman calves gained more than European breeds (Peacock et al., 1966). It is suspected that a Brahman or Brahman-cross would provide the best point of departure, followed by rigorous selection. Experiments of the above nature coupled with investigations of forage intake and nutrient quality would provide much needed answers for the range cattle industry of Florida.

The stocking rate of cattle in this study was approximately 0.361 cows per hectare per year. The average weight of the animals on the pasture was about 383 Kg per pasture or around 93.3 Kg of cow per pasture per year. The average biomass of the two groups of arthropods was estimated to be about 100 Kg per pasture during one week in the latter part of September.

There is considerable room for doubt as to the validity of the estimates of arthropod biomass. However, the fact remains that this estimate only represents two groups of the crawling arthropods and the soil and aerial populations were not sampled. Gryllus species are primarily omnivorous and the spiders are predators, so their impact on the vegetative portion of the site may not be as great as the biomass numbers would indicate. Other herbivorous insects were noted at different times in rather large numbers, grasshoppers in particular, in the late spring. One sampling does not adequately sample the insect population over the course of the year, but it does point out that the biomass of the arthropod population may be quite significant with respect to the biomass of the larger herbivores of the area. This area should be researched further.

Specific recommendations for use of native flatwood ranges in Florida based on the results of this investigation are: Use a Brahman or Zebu type animal, and/or follow a rigorous selection program. The native range should be used primarily for dry cows, supplemented with energy (molasses with protein). Phosphorus should be supplied in order to rectify the Ca:P imbalance of the native feeds. Calcium should not be fed, or should be at low levels with respect to P, if put on offer.

CHAPTER 11

CHEMICAL ANALYSIS AND IN VITRO DIGESTIBILITY OF THE FRONDS OF SERENOA REPENS (SAW PALMETTO)

Introduction

Saw palmetto (Serenoa repens) is a common component of the understory of much of the Coastal Plains of the Southeast. Saw palmetto is considered to be an invader species (although the rate of invasion is slow) and was probably held in check by the competitive effects of other native species and periodic wildfires prior to the advent of modern man. With the control of fires, the heavy grazing pressure on the range areas and the establishment of plantation tree farming, crown cover of saw palmetto has increased to about 20%, especially in Southern Florida (Hilmon, 1968). The main economical value of saw palmetto is in the use by the honey industry, though wildlife (deer, turkey, bear) eat the drupes, and in the case of the Florida bear, may at certain times of the year provide a substantial portion of the diet (Halls, 1977). Presently, mechanical control appears to be the best method of eradication, with roller chopping giving good results (Carter, 1973).

It was widely believed that cattle would only graze saw palmetto when forced to eat it through lack of other suitable forage (Hilmon, 1968). However, it was noted on the flatwoods at the BRU that cattle grazed saw palmetto, even in the presence of adequate forage, often grazing it when they were first turned into the pasture. In view of the striking symmetrical pattern of grazing of the fronds (Figure 11.1.), it was surmised that the top portion of the buds were being grazed; this was later substantiated by direct observation.

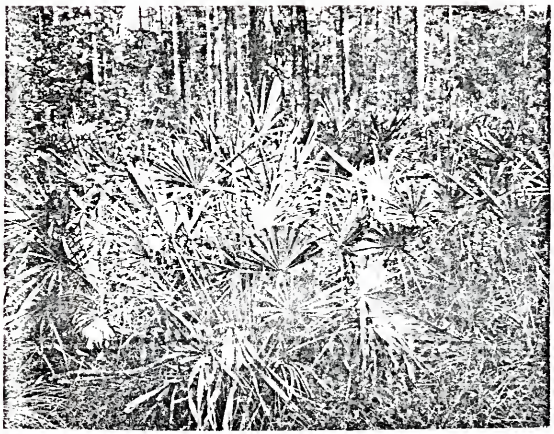

Figure 11.1. Symmetrical pattern of defoliation by cattle on Serenoa repens.

Cattle, when initially placed on rangeland, will usually sample many different species at first, and later will tend to concentrate on only a few preferred species (Stoddart and Smith, 1955). In the case of saw palmetto, it was observed that cattle would first eat the outer portion of the fronds, but after a short adjustment period (one or two days) would concentrate on the buds and only occasionally graze the fronds. In order to investigate the reason for the preference for the bud, especially the top portion, the following study was conducted.

Materials and Methods

The collection site was located on an ungrazed plot in replication IV. This site had been burned in February 1974 and again in February 1976. Collections were made from five plants randomly selected from within the pasture in October 1977. In addition to the bud, four other fronds were selected in descending order down the plant stem (Figure 11.2.). Each frond was divided into an outer and inner portion, with respect to the petiole, with only the frond material sampled. Each sample was ground and split into two portions, one for chemical analysis (P, Ca, and K) and the other for *in vitro* digestibility. Analysis of the data was with a randomized complete block design for ANOVA.

Results

The chemical content between the outer and inner portion of the fronds was not found to be different at the $P < 0.05$ level (Table 11.1.). However, there was a strong trend for the outer portion to be higher in chemical content (all three elements) than the inner portion.

The IVOMD and chemical values for the inner and outer portions of the frond were composited and set up as a randomized complete block design, with the fronds as the treatment and the plant as the blocks. Table 11.2. lists the results of this analysis. The difference for the table was calculated at

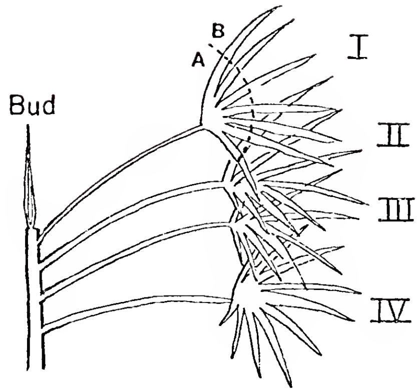

Figure 11.2. Collection profile of Serenoa repens.

Table 11.1. *In vitro* digestibility and chemical content (P, Ca, and K) or *Serenoa repens* fronds.

	% *in vitro*			P (ppm)			Ca (ppm)			K (ppm)		
	$\bar{X}$	s	CV	$\bar{X}$	s	CV	$\bar{X}$	s	CV	$\bar{X}$	s	CV
Bud A[1]	13.51	1.13	8.4	1003	92.0	9.2	799	200.0	25.0	8727	974.0	11.2
Bud B	13.74	1.90	13.8	1210	188.5	15.6	941	210.6	22.4	8312	673.1	8.1
1 A	17.30	2.32	13.4	808	33.0	4.1	869	226.8	26.1	4703	1728.7	36.8
1 B	17.75	2.16	12.2	861	58.1	6.7	1181	363.5	30.8	5448	1975.1	36.3
2 A	19.10	1.90	10.0	686	50.5	7.4	1744	330.4	18.9	2867	1502.3	52.4
2 B	19.23	1.70	8.9	697	120.8	17.3	2142	1134.4	53.0	3038	2045.1	67.3
3 A	18.12	3.24	17.9	668	53.2	8.0	1733	576.3	33.3	2244	651.3	29.0
3 B	20.23	2.40	11.9	722	121.1	16.8	2255	757.9	33.6	2826	1281.7	45.4
4 A	20.22	1.86	9.2	612	84.2	13.8	1998	354.0	17.7	1708	772.3	45.2
4 B	17.50	1.48	8.5	559	157.7	28.2	3330	536.4	16.1	1543	815.1	52.8

1. A - The one half portion of frond closest to petiole.
   B - The one half portion of frond furthest from petiole.

Table 11.2. Statistical differences of composited fronds of *Serenoa repens* for *in vitro* digestibilities and chemical compositions (P, Ca, and K).

	Frond position				
Characteristic	Bud	1	2	3	4
In vitro (%)	13.6	17.8	19.8a	19.7a	18.8a
P (ppm)	1094.0	835.0	692.0a	695.0a	488.0
Ca (ppm)	929.0a	1025.0a	1943.0b	1994.0b	2722.0
K (ppm)	8898.0	5082.0	2952.0a	2536.0ab	1096.0b

the $P < 0.05$ level, however the difference between the bud and the rest of the fronds was found to be different at the $P < 0.01$ level, for both chemical and *in vitro* analysis.

The Ca:P ratio was calculated for each of the fronds, both inner and outer portions (Table 11.3.). The lowest ratio occurred in the outer portion of the bud, (.78) and increased with the age of the frond.

Discussion and Conclusion

Hilmon (1968) reported that it requires between three and seven years after a fire for saw palmetto to return to an average frond production of five per year, with an average of seven to eight fronds being produced the first year, and three the second year. Consequently, the samples taken in descending order along the stem represent a loose aging criterion with the oldest being the lowest on the stem. As noted from Table 11.2., phosphorus and potassium decreased with frond age and calcium and *in vitro* digestibility increased.

Charley (1977) points out that generally up to 90% of phosphorus may be returned to the shoot; potassium is more variable in behavior but is usually withdrawn in most species and calcium often increases with age of the leaf. Ovington (1968) reports that potassium leaches out from plant tissue with relative ease, calcium more moderately and phosphorus with difficulty. The data for the chemical composition of the fronds as a function of age are not out of line with that reported in the literature, even though saw palmetto was not specifically studied in these reports. The interesting aspect of increased digestibility with increasing age is not so readily explainable. A linear regression (eq. 1) was performed in an attempt to relate increase of calcium content with that of digestibility ($r^2 = 0.394$). A higher r^2 was determined with a multiple regression (eq. 2) with phosphorus and calcium as the independent variables. This demonstrates Van Soest (1967) arguments concerning using

Table 11.3. The Ca:P ratio of *Serenoa repens* fronds.

Frond position		Ca:P
Bud	A	0.80
Bud	B	0.78
1	A	1.08
1	B	1.37
2	A	2.54
2	B	3.07
3	A	2.59
3	B	3.12
4	A	3.26
4	B	5.96

more than one component to predict digestibility. Obviously, there are numerous factors affecting digestibility and to select any one factor as the predominant one is to imply a relationship that may or may not exist.

Young leaves of plants, under optimal moisture conditions, generally have higher rates of photosynthesis than do older leaves (Moore, 1977). The fact that more P and K were found in the outer portion of the tip and leaves (Table 11.1.) would tend to support the contention that the tips were more metabolically active than the inner portion of the fronds, and hence more palatable.

Nutrient removal, either via translocation or leaching, would explain the differences noted in saw palmetto fronds as the age of the frond increases. The increase of in vitro digestibility from the bud to the older fronds may be due, in part, to the increased calcium content of the more mature fronds, however, more research is needed in this area.

The preference by cattle for the top portion of the bud may be due to the location of the bud (the bud is about head high, with respect to cattle), the configuration (a small package, compared to the more leafy frond), or perhaps the lessor amount of fiber in the bud than in the more mature fronds. However, this preference is more likely due to some inherent ability of the animal to recognize a source rich in phosphorus and satisfy its requirements in this manner. The ability of cattle to select proper rations of minerals to satisfy nutritional requirements has been claimed by some to have been lost through domestication (Coppock, et a., 1976). Specific appetites for certain substances has been noted in rats (Scott, 1950), though phosphorus was not one of the nutrients investigated. Coleman and Barth (1972) noted that animals selected forages higher in protein and digestibilities than were observed in the available forage sample. Leigh (1961) found that livestock accepted grass cultivars

highest in phosphorus and potassium before those with low contents of these minerals.

The fact that the Ca:P ratio of most of the forages tested is high, (sample diets were found to have a ratio of 5:1, Chapter 10), would make any forage with a low ratio attractive to the animal. With the possible exception of an undetected exotic compound that makes the outer portion of the bud more desirable to cattle, there appears to be little reason for the preference noted, other than the low Ca:P ratio.

More research is needed to determine if this ratio exists year round or just in the fall, when these samples were collected. Since the cattle diet has the greatest proportion of S. repens in the winter (31%), over 16% in the spring and fall and only 7% in the summer, either S. repens has the lowest Ca:P ratio during fall, winter and spring months or the animals are selecting plants in the summer (possibly legumes) that have a higher P content in an effort to maintain a favorable Ca:P ratio. This entire area of animal selection should be investigated further.

The observed fact that cattle were selecting exactly that portion of the frond that had the lowest Ca:P ratio would substantiate the argument for an inherent ability to select foods high in needed nutrients. Basiciomycetes comprise a large portion (up to 60%) of the deer diet (Harlow, 1961; Harlow and Jones, 1965) and these plants have a higher level of P content (1%), (Mulder et al., 1969) than most range plants. This high utilization of fungi might be a response of the deer to the high Ca:P ratio found in most of the other components of their diet.

CHAPTER 12

DECOMPOSITION OF PLANT AND FECAL MATERIAL

Introduction

In the absence of herbivores, minerals cycle from the soil to plants, to litter, and back to the soil. Grazing adds more pathways since minerals are shunted to animals and deposited as dung or urine, which decompose at different rates than unaltered plant material (Heady, 1975). In a study of herbivory in grasslands, Grant and French (1975) reported that the turnover time of minerals entering the soil was considerably reduced by the presence of herbivores. The rate of turnover time was increased by as much as 2.8 times over the rate for a system without herbivory. Petersen et al. (1956a) determined that a mature cow produced 25 Kg of dung and 9 Kg of urine daily. Most of the voided P occurred in the dung and the urine was richest in N and K.

Cattle deposit their excreta haphazardly while grazing. However, since they tend to bunch up at night there is usually a higher fecal count on the bedgrounds, or for that matter, any place where cattle tend to congregate (Hafez et al., 1969). Numerous investigators have reported on the distribution patterns of grazing cattle (Petersen et al., 1956a; Richards and Wolton, 1976). Changes in botanical composition are believed to be due, at least in part, to the deposition of dung and urine. Sears (1956) reported that dung and urine were responsible for an increase noted in the grass component and a decrease in the clovers. Other investigators have reported similar conclusions (Heady, 1975; MacDiarmid and Watkin, 1971).

Petersen et al. (1956b) suggest that the greatest benefits from excretal return for P and K are under conditions of high stocking rates. MacDiarmid and Watkin (1972) suggest that the loss due to fecal contamination and avoidance by cattle are not as great as it would seem. They noted that cattle do not graze areas around fecal droppings or urine spots as close to the ground as in uncontaminated areas. However, because of the increased plant growth around the dropping and later, in it, the actual amount of forage removed is the same or greater than if the dropping had not been present. The same effect from other herbivores would differ in amount rather than in principle.

Most of the studies involving nutrient cycling through cattle have been done in humid pasture environments and very few under range conditions. Effects of fertilization and the movement of fertilizers in the soil have been studied in Florida (Chapter 4) but the effects of grazing on the rate of decomposition has not been investigated. This would be a fertile field of research.

Different plants do not decompose at the same rate even under the same environmental conditions (Williams and Gray, 1974). An experiment conducted in England, using two different size mesh litter bags, noted a higher rate of loss for the larger mesh, this difference was attributed to the presence of small invertebrates (Bocock, 1964). The bottleneck in mineral cycling rest in the slow decomposition of organic matter. Management practices to increase this rate would result in a faster turnover rate, hence an increase in annual production.

This present study was designed to provide an indication of the rates of dung decomposition and the consequent movement of minerals into the soil. Also of interest was the decomposition of a highly digestible range grass and one of the more common plants found in Florida, S. repens, and the role that insects play in the decomposition process.

Materials and Methods

The fecal decomposition study was begun 27 July 1977 and concluded 13 March 1978, a total of 228 days. The control pasture in replication IV was selected as the study site. The study plot was selected so it would be in the open, not subject to canopy effects. A grid was laid out 1.22 m on a side, nine evenly spaced sampling positions were selected, with one position in each corner of the grid. Soil samples were taken, at each (5 cm intervals) to a depth of 25 cm. After sampling these were plugged with soil and marked with golf tees. Three positions in this grid were randomly selected for controls.

Fecal material was collected from the feed yard at the BRU, thoroughly mixed, and three samples removed for percent water, P, Ca, and K determinations. The fecal material was shaped into circular pies, 20.3 cm in diameter and 4.4 cm in height, and weights of each sample recorded. The pies were placed on the grid, slightly off to one side of the golf tees.

A second group of samples was positioned in two rows 0.7 m apart. Five samples were placed in each row 0.7 m apart. In one row the sample was laid on a nylon mesh, the ends folded over and stapled together. Six soil samples were taken, three to a row at intervals of 5 cm to a depth of 25 cm.

The samples were collected on 13 March 1978, weighed, dried, and percent moisture determined. Three samples were analyzed for P, Ca, and K. Soil samples were taken at five depths (5 cm intervals), under each sample at least 2 cm away from the golf tee, and analyzed for P, Ca, and K.

Amounts of P, Ca, and K present in the original sample were determined from the dry weight of the sample and the percent of the nutrients present. At the conclusion of the experiment three fecal samples were collected, sand removed, dry weights and percent of each nutrient determined. The difference between these two values represents the amount of each nutrient that has been removed from the original sample.

Soil samples were taken on one unmeshed pie in the two rows of five samples each. The sampling format was in the form of a cross. One soil core (5 cm interval, depth to 25 cm) was taken directly under the center of the pie, four cores taken at the edge of the pie (12.7 cm from the center) and four cores 17.8 cm from the center of the pie. Any surface manure was removed prior to sampling.

On 16 May 1977 a quantity of Panicum anceps was collected from the 6 month pasture in replication I and dried at 70°C for three days. Aliquots of approximately one-half gram were taken and placed in nylon (1 mm) mesh bags measuring 10 by 15 cm. Eighty samples were placed in bags and the ends stapled together (control bags) and additional 80 samples were placed in bags with the ends held open by two wire stays (treatment bags). Five bags of each type were placed in pairs in each pasture in an X position; one pair in the center and the other pairs 26 m away, toward the corner of each pasture. The two bags (treatment and control) were placed 15 cm apart and the position marked. Twenty closed litter bags containing S. repens were placed in replication IV, five to a pasture, each sample placed within 20 cm of the P. anceps samples. All bags were in position on 24 May 1977 and collected 13 March 1978 (292 days).

Upon collection of the sample excess sand was brushed off, dried at 70°C for 48 hours and the contents weighed. Ten bags were composited and ashed in a muffle furnace at 500°C for four hours. The light ash was floated off with water, the remaining sand was dried and weighed. Percent of the P. anceps remaining was computed with allowances made for the residual sand. Chemical analysis of the P. anceps was conducted for P, Ca, and K.

A t-test was the method of statistical analysis used for this study, when $P < 0.1$. The results are considered non-significant (ns). Comparisons made were between the initial nutrient level of the site (1977) and the control

(no fecal material) at the end (1978), soils under the samples and the controls, nutrient content under the samples compared to the same site at the initiation of the experiment, and the treatment bags and the controls.

Results

The soils of the study site show a general increase in nutrient content from July 1977 to March 1978. An increase was noted at all depths for P and all but 5 - 10 cm depth for K. This increase was noted for Ca, only in the deepest layer. These increases were generally found to be different ($P < 0.1$) for P and K (Table 12.1.). A comparison of the nutrient levels under positions in the nine sample grid indicate differences only for P and K in the upper two levels of the soil profile (Table 12.2.).

Comparing the soil cores taken in 1976 to the cores taken at these same locations under the fecal samples (1977) shows increases for P and K ($P < 0.1$). Only the top two soil layers show an increase for Ca (Table 12.3.).

Sampling in a cross mode, at the center of the pie, the edge and slightly beyond the edge, gave a generalized picture of the movement of the nutrients into the soil. Since only one sample point was available the results were averaged for each equal radius and are presented in Table 12.4. To show the uneven movement of nutrients into the soil, P content of the soil at the five depths was listed for the north-south and the east-west arm of the cross (Table 12.5.). The area has a gentle slope to the south and east, this is reflected by the apparent concentration of P in these directions.

The composition of the initial fecal material is compared to the analysis of the material at the completion of the experiment (expressed as ppm, 1976 presented first followed by 1977 analysis for each nutrient): 22657:11677, P; 20319:25086, Ca; 4714:680, K. These figures represent a percent change of -48.5, 19.0, and -85.6, for P, Ca, and K, respectively.

Table 12.1. Change in soil nutrient content, July 1977 to March 1978 in the controls at different depths.

Depth (cm)	Date	P (ppm)	Level of significance	Ca (ppm)	Level of significance	K (ppm)	Level of significance
0 - 5	1977	0.9	.10	186	ns	5.9	.01
	1978	1.7		129		8.0	
5 - 10	1977	0.6	.01	109	.05	6.3	ns
	1978	1.5		60		5.3	
10 - 15	1977	0.8	.10	79	.02	4.0	ns
	1978	2.6		51		5.3	
15 - 20	1977	1.2	.05	75	ns	1.9	.01
	1978	7.2		56		4.0	
20 - 25	1977	1.4	.01	83	ns	2.9	ns
	1978	6.4		111		4.0	
			4 degrees of freedom				
All depths composited	1977	1.0	.01	106	ns	4.2	ns
	1978	3.6		81		5.3	
			28 degrees of freedom				

Table 12.2. Average value of nutrients underneath fecal samples, compared to control, at different depths, for the March 1978 collecting date.

Depth (cm)	Control (C) Sample (S)	P (ppm)	Level of Significance	Ca (ppm)	Level of Significance	K (ppm)	Level of Significance
0 - 5	C	1.7	.02	129	ns	8.0	.02
	S	40.9		258		24.7	
5 - 10	C	1.5	.10	60	ns	5.3	ns
	S	12.4		78		12.7	
10 - 15	C	3.5	ns	51	ns	5.3	ns
	S	11.9		61		8.7	
15 - 20	C	7.2	ns	56	ns	4.0	.05
	S	12.8		73		8.0	
20 - 25	C	5.1	ns	111	ns	4.0	ns
	S	14.9		93		8.0	

7 degrees of freedom

Table 12.3. Average nutrient content of soil under fecal sample (1978) compared to soil nutrient content in 1977.

Depth (cm)	Date	P (ppm)	Level of Significance	Ca (ppm)	Level of Significance	K (ppm)	Level of Significance
0 - 5	1977	1.0	.001	179	ns	7.3	.01
	1978	40.9		258		24.7	
5 - 10	1977	0.8	.02	97	ns	5.1	.05
	1978	12.4		78		12.7	
10 - 15	1977	1.8	ns	75	ns	3.1	.02
	1978	12.2		62		8.7	
15 - 20	1977	0.8	ns	77	ns	1.7	.001
	1978	12.8		73		8.0	
20 - 25	1977	0.8	.10	73	ns	2.1	.02
	1978	14.9		93		8.0	

10 degrees of freedom

Table 12.4. Average nutrient concentration under fecal sample, at the center and 12.7 and 17.8 cm from center at five depths.

Depth (cm)	Average nutrient concentration under fecal sample (ppm) Center			12.7 cm (edge)			17.8 cm		
	P	Ca	K	P	Ca	K	P	Ca	K
0 - 5	64.8	300	20	45.5	292	19	15.0	183	12
5 - 10	16.1	68	8	30.6	77	12	13.8	73	9
10 - 15	4.6	48	8	17.7	95	8	15.5	56	6
15 - 20	7.6	52	4	8.3	50	5	8.9	49	4
20 - 25	11.0	44	4	13.6	64	6	5.8	63	4

Average nutrient concentration in control (ppm)

Depth (cm)	P	Ca	K
0 - 5	1.6	129	8
5 - 10	1.5	60	5
10 - 15	2.6	51	5
15 - 20	7.2	56	4
20 - 25	5.1	111	4

Table 12.5. Phosphorus profile below fecal sample (one sample).

	Distance from center of sample (cm)				
Depth (cm)	17.8	12.7(edge)	0	12.7(edge)	17.8
			East - West Arm		
0 - 5	30.7	66.7	64.8	41.4	2.3
5 - 10	38.3	66.7	16.1	14.3	2.6
10 - 15	46.9	17.1	4.6	4.4	7.2
15 - 20	16.0	8.5	7.6	5.3	7.1
20 - 25	7.3	30.3	11.0	7.5	4.9
			North - South Arm		
0 - 5	16.9	66.7	64.8	7.1	10.2
5 - 10	2.2	8.3	16.1	33.0	12.0
10 - 15	4.2	3.3	4.6	46.1	3.7
15 - 20	8.4	10.6	7.6	8.8	4.2
20 - 25	6.6	10.4	11.0	6.2	4.2

The average amount of nutrients that were found to have been removed from the original fecal sample were (in grams); 7.5, P; 4.1, Ca; and 2.0, K. This represents a loss from the original of 69.4, 36.9, and 90.9% for P, Ca, and K, respectively.

The average of each soil depth (the cross soil analysis), less the average for each depth from the controls (nine point grid) have an incremental increase (due to the presence of the fecal material) at each depth for each element in the column (17.8 cm diameter) under the fecal sample. With the bulk density of the area as 1.31 (g/cc (Chapter 4), total amount of nutrient in the column under the fecal sample was determined; these values were 0.5, 1.1, and 0.2 g for P, Ca, and K, respectively. Subtracting these values from the amounts known to have been removed from the original samples leaves 7.0, 3.0, and 1.8 g of P, Ca, and K, respectively, unaccounted for.

There was some disturbance noted in the two row plot. All of the fecal material in the nylon bags had been destroyed or removed and all but one of the un-meshed samples disturbed. The samples in the nine point grid were unmolested. Unfortunately, this damage was not noted until sampling in the nine point grid had been complete, otherwise more grids could have been obtained.

Of the 160 litter bags set out, 89 were retrieved, 43 treatment and 46 controls. The percent of plant material lost from the bags was found to be different at the $P < 0.05$ level. The treatment bags had an average loss of plant materials of 55.3% and the control bags, 59.0%. The percent decomposition did not show any effect due to the different grazing treatments imposed on the pasture. Chemical analysis of _P. anceps_ at the time of collecting was (in ppm); 941, P; 4951, Ca; and 780, K. The original sample material had been lost before a chemical analysis was made, however the one spring 1977 collection of _P. anceps_ (Appendix E, Tables E.1., E.2., and E.5.) gave the following

analysis (in ppm): 1055, P; 3794, Ca; and 12114, K. None of the 20 bags containing S. repens were recovered.

Discussion and Conclusions

In chapter 4 it was noted that P, Ca, and K were found to have increased in the control and four-month rest (replication IV) from 1977 to 1978. This same general increase was noted again in the control. Since the measurements did not occur on the same date each year, a seasonal or cyclic effect of mineral availability, related to amount of precipitation, or seasonal uptake by plants is one possible explanation. The other possibility is that the system is in a dynamic state as opposed to steady state or climax. The second explanation appears to be the most logical. There was an increase of litter noted for the area as a whole, which is probably in response to the burning of the area in 1976. This accumulation and resulting decomposition coupled with a fire cycle would be the mechanism responsible for the general increase noted. A possible line of inquiry would be to take soil samples, at regular periods of time during the course of the year, in such a fire climax site, and note if there is a seasonal cycle and/or one related to fire.

At the completion of the experiment the shape of the original pies was quite discernable, however, the material had deteriorated to the point where it could no longer be picked up in one piece. There was a general lack of rain after the samples were positioned. This resulted in a general drying out of the entire sample with a resultant crust forming on the surface. This crust would cause a lesser degree of water penetration. Water would move over the sample to the edge and into the soil. This movement would cause higher concentrations at the edges of the sample than directly under it. Higher concentrations were noted on two sides of one sample (Table 12.5.).

Of the six samples that had measurements taken directly under the sample, three had the same level or higher P levels in the 5 - 10 cm level than in the 0 - 5 cm level. This was masked when the averages were taken. A case for lateral movement as discussed in Chapter 6 is suggested by Table 12.5. The 10 - 15 cm depth at 17.8 cm from the center of the sample shows higher levels of P than the levels above it on the eastern portion of the measured cross. The slope of the surface at this sample was about 1% to the east. Runoff from the surface of the sample to this area with dilution of the two surface layers and a concentration of P at the 10 - 15 cm layer could also be responsible for this result.

The increase in Ca content in the remaining fecal material is interesting. Apparently Ca content increased due to the high cation capacity of organic material in the sample, much as it is known to do in organic soils (Brady, 1974).

The top two layers of the soil were the only ones that showed a meaningful increase in nutrients when compared to the controls sampled at the same date (Table 12.2.). MacDiarmid and Watkin (1972) noted an increase in P at the 30 cm depth in 55 days. These authors also reported a first flush of nutrient increase at depths of 20 cm in 10 days then a dropping off in concentration followed by another increase at 55 days, with deeper depths also affected. They did not report rainfall data during their experiment.

The experiment by the above two authors was carried out on a silt loam soil. Movement of P would be expected to be slower on such a soil than in a sand. The movement of the bulk of the nutrients contained in the sample past the 25 cm depth is not ruled out. If this were the case, it would explain the lack of correlation with the nutrients known to have left the sample material and the amount detected in the column underneath it. Concentration of P and K in the soil column could be increased by 500%, and there would still be considerable material left unaccounted for.

Rates of decomposition for the grass Molinia caerulea, in a temperate forest are 30% the first year and 40% thereafter (Bell, 1974). Rates for grasses in Florida are not known to this investigator. P. elliottii takes about three years to decompose to the state of being unrecognized as pine needles (Pritchett, 1976). Panicum anceps is a highly digestible range grass (55% in vitro digestibility in the spring, Table E.1.), a 59% loss in 292 days does not appear to be out of line, considering the warm humid conditions that exist in Florida.

The difference noted between the two types of bags was opposite to that expected. It was believed that by opening the bags on one end, insects would have been able to enter, and their effects noted. Apparently, the open bags resulted in a less preferred micro-climate for the decomposer organisms, and this resulted in the effects noted.

It would appear that the use of green nylon bags is not to be recommended for litter decomposition studies. All of the bagged fecal material had been destroyed or disturbed by some animal, and slightly less than half of the P. anceps litter bags could not be found, or if found, had been molested. None of the S. repens could be located after a diligent search. Cattle were the culprits in at least one case, as mesh material was noted in a fecal dropping. Armadillos and perhaps possums are suspected of doing the most damage. It is debatable whether it was the color of the bags or the material they contained that was responsible for the loss. Since location markers were present at the conclusion of the experiment, something apparently makes these bags attractive to the local inhabitants.

There is considerable room for investigation as to movement of various elements in a native flatwoods site. Setting out fecal samples in sufficient replications and monitoring over time using a contour type sampling procedure, as

in this study, would provide much needed information as to the rate of nutrient movement in a Florida flatwoods.

CHAPTER 13

NUTRIENT INCREASES DUE TO OUTSIDE INPUTS

Introduction

The beneficial effects of rainfall to plants, aside from satisfying moisture requirements has been known for some time. Lebedjantzev (1924) commented on the robust appearance of plants following a rain, effects that did not appear to be the result of water alone. Numerous investigators have measured the mineral influx into various systems due to rainfall. Fried and Broeshart (1967) reported a range of 2 to 45 Kg/ha/yr of N as a worldwide average. Values for Ca range from 8 Kg/ha/yr (Likens et al., 1967; Richardson and Lund, 1975) in a northern forest, to 29 Kg/ha/yr in a moist tropical forest (Golley, 1975). These atmospheric inputs are not constant, considerable variations existing from one month to another (Sollins and Drewry, 1970). Ewell et al. (1975) found significant differences between chemical content of summer precipitation and winter precipitation in the Gainesville, Florida area.

The amount of nutrient loss from a system will determine the net effects atmospheric inputs will have. A hypothesis put forth by Vitousek and Reiners (1975) suggest that nutrient retention increases as a function of maturity to a point, then decreases as the system ages. The pine flatwoods of Florida are not a mature system in the usual sense of the word, but are defined as a fire climax (Laessle, 1942). The nutrient rate of loss in this system is not believed to be large (Chapter 4), consequently the result of atmospheric inputs could play a significant role in determining the quality of the site.

It is accepted that 80 - 95% of all ingested nutrients are returned to the soil in the excreta of domestic livestock (Heady, 1975). Hutton et al. (1967) found that dairy cattle retained less than 10% of any element. Pieper (1974) noted that the sale of calves accounted for the bulk of nutrient loss to a range system in New Mexico. Any growth increment of an animal would result in nutrient being removed from a system. However, if the animals were mature, and not gaining weight, the nutrients removed would only be that amount deposited in the various organs and would represent minimal loss to the system.

Most would intuitively agree that if supplements are added to a pasture there would be a residual effect of these supplements on ensuing production from that pasture. There has been little definitive studies on this aspect. (Mott (1977)[11] has pointed out such effects on a pasture in Indiana. This effect is implied in a study in South Florida on blood and bone composition from animals on different pastures receiving different levels of P fertilizers (Kirk et al., 1970).

This study does not attempt to give definitive values to the effects of outside inputs to a grazing system, but only to point out the magnitude of such inputs as they exist in a flatwoods system.

Materials and Methods

Railfall at the study site was collected for five months (May through September 1977) in a plastic rainfall guage. Water samples were sent to the University of Florida Soil Testing Laboratory and analyzed for pH, NO_3, NH_3, P, Ca, K, and Mg. The amount of each of the above chemicals deposited per hectare were determined from the amount of precipitation that fell during the five month period, rainfall data monitored at the BRU farm (Chapter 3). This

11. G. O. Mott. 1977. Prof. Agron. Dept., Univ. Fla., Personal communication.

was based on one centimeter of precipitation per hectare equalling 1.0×10^5 Kg. Yearly estimations were made based on average depositions for the five month collection period. Linear regressions (eq. 1), relating the amount of precipitation to nutrient content in the same, were made.

The cattle were fed a mineral supplement during the entire course of the experiment. The number of cattle that were on each pasture and the duration of grazing, allowed the number of total cow-days for each grazed pasture to be calculated for the length of the study. It was assumed that since these were mature cattle, all the minerals ingested would be returned via feces and urine to the pasture. The average consumption of 0.18 Kg/day/cow of mineral mix was determined by the number of animals, the duration of access, and the total amount consumed. The total cow-days for each pasture for the duration of the experiment was used to determine the amount of mineral being deposited, this is expressed in three ways: the actual amount deposited in Kg; the amount this would represent if it was mixed with the top 30 cm of soil (bulk density of 1.37 g/cc); and the percent increase this represents from the 1977 soil test data (Chapter 4).

Twenty-five samples of collected fecal material (cow pies) were randomly selected from all the samples that had been collected for determination of forage intake (Chapter 10). These were prepared and analyzed for P, Ca, and K, at the soil testing laboratory. Chemical analysis of the supplement was obtained from the mineral tag.

Linear regressions (eq. 1) were made relating the amount of mineral deposited in each pasture to the foliar content of the fall collection of eleven species made in each pasture (Chapter 8).

Results

The results of the chemical analysis of rainwater collected at the study site (16 samples) indicated a surprisingly high amount of Ca (Table 13.1.). The pH averaged about 5, except in June when it rose to 7.1. The N content was lower in this month and the Ca content was high, apparently resulting in a pH near neutral. The data from Table 13.1. were used to construct the average amount of minerals deposited per hectare during the five month period. These values were divided by the amount of precipitation that fell during that period, multiplied by the total amount that fell during the course of the experiment (August 1976 to August 1977) to obtain an estimation of the total yearly input to the system (Table 13.2.).

The linear regression equations relating the different minerals to the amount of precipitation were not meaningful, r^2 values less than 0.16. A high r^2 (0.92) value was obtained for NO_3 and the amount of precipitation that fell during May and June, however there were only four data points, which leaves only one degree of freedom for error. The May and June rains were typical thunderstorms with attendant lightning. Whether this is a cause and effect relationship cannot be concluded from the collected data.

The chemical content of the mineral mix (tag data) and the average amount consumed per head per day for each mineral is presented in Table 13.3.

Of particular interest is the high increase computed for P on some of the pastures (Table 13.4.). For example, 35.9% increase for the four-month rest pasture in replication IV. This pasture had a soil P content of 0.9 ppm and the relatively small increment added (0.9 Kg) resulted in a large increase in the total soil P content.

The chemical analysis of the 25 randomly selected cow pies indicated an average chemical content of 6833, 17042, and 2458 ppm for P, Ca, and K, respectively. The average weight was 484 g for these 25 samples. The amount of

Table 13.1. Chemical content and pH of rainwater collected from May through September 1977 at the BRU.

Component	Month				
	May	June	July	August	September
Precip. (cm)	7.77	8.43	16.54	13.06	17.25
pH	4.35	7.10	4.15	5.30	5.10
NO_3 (ppm)	4.31	2.50	1.59	1.40	1.53
NH_3 (ppm)	3.39	.58	.16	.18	.17
P (ppm)	.05	.20	.05	.04	.05
Ca (ppm)	.65	2.88	.94	3.33	2.10
K (ppm)	.40	.95	.65	1.20	.42
Mg (ppm)	.15	.30	.18	.19	.22
Number of samples	2	2	2	4	6

Table 13.2. Quantity of minerals deposited on study site during five month collection period (May - September 1977) and year total (August 1976 - August 1977).

Mineral	Five month total	Year total[1]
NO_3 (Kg/ha)	12.56	21.81
NH_3 (Kg/ha)	3.91	6.79
P (Kg/ha)	0.43	0.75
Ca (Kg/ha)	12.46	21.66
K (Kg/ha)	4.48	7.79
Mg (Kg/ha)	1.30	2.26
Precip. (cm)	63.05	109.58

1. Computed based on amount deposited in five month divided by the precipitation in that period (63.05) times the total precipitation that fell from August 1976 - August 1977 (109.58 cm).

Table 13.3. Mineral content of supplement and estimated daily consumption rate of each mineral.

Mineral	% in supplement[1]	Amount ingested[2] per cow-day, g/day
P	7.0	12.44
Ca	15.0	26.66
Mg	2.0	3.55
Fe	1.0	1.78
NaCl	25.0	44.43
Cu	0.15	0.27
Mn	0.20	0.36
Zn	0.40	0.71
Co	0.03	0.05
I	0.04	0.07
Fl	0.08	0.14

1. Tag data.
2. Based on daily consumption of supplement of 0.18 Kg/day/cow.

Table 13.4. Amount of mineral in mineral supplement estimated to have been returned to each pasture and compared to 1977 soil analysis

Pasture (Replication - month rest)	Total[1] cow-days	P			K			Mg		
		Kg[2]	ppm[3]	% Increase[4]	Kg[2]	ppm[3]	% Increase[4]	Kg[2]	ppm[3]	% Increase[4]
I - 2	149	1.85	0.67	8.0	3.97	1.43	1.3	0.53	0.19	1.7
I - 4	97	1.21	0.44	25.9	2.50	0.93	0.6	0.34	0.12	0.4
I - 6	138	1.72	0.62	22.9	3.68	1.33	0.9	0.48	0.17	0.9
II - 2	177	2.20	0.79	9.4	4.72	1.70	1.7	0.63	0.23	2.5
II - 4	107	1.33	0.48	11.7	2.85	1.03	0.9	0.38	0.14	1.0
II - 6	65	0.81	0.29	17.1	1.73	0.63	0.5	0.23	0.83	0.6
III - 2	201	2.50	0.90	21.0	5.36	1.93	1.5	0.71	0.26	1.9
III - 4	95	1.18	0.43	6.4	2.54	0.91	1.2	0.34	0.12	1.6
III - 6	77	0.96	0.35	2.7	2.05	0.74	0.7	0.27	0.10	1.3
IV - 2	138	1.72	0.62	29.5	3.68	1.33	1.3	0.49	0.18	1.8
IV - 4	72	0.90	0.32	35.9	1.92	0.69	0.7	0.26	0.09	0.7
IV - 6	135	1.68	0.61	13.2	3.60	1.32	1.3	0.48	0.17	2.0

1. Total number of cow-days during experiment
2. Kg's of mineral in supplement returned to pasture via excreta.
3. Estimated ppm base on a bulk density of 1.37 g/cc for top 30 cm soil.
4. Percent increase over 1977 soil analysis data (Chapter 4).

each mineral contained in an average cow pie is 3.31, 8.25, and 1.19 g for P, Ca, and K, respectively.

No meaningful relationship was determined in the comparison of the foliar P levels to the pastures having the greatest increase in P through mineral supplementation. This fact is not too surprising since most of the P from the mineral supplementation was still retained in the fecal material (Chapter 12).

Discussion and Conclusions

The values determined for nutrient input from rainwater are not offered as the actual amounts deposited on the site. This portion of the investigation only spanned five months, with 16 rainfall samples analyzed. In a mineral cycling study near Gainesville, Ewel et al. (1975) reported that winter precipitation contained significantly more nutrients than in the summer period. With the possible exception of N and Ca, the values presented would be lower than the yearly average.

The amount of N present appears to be high compared to values given in the literature of 2 to 10 Kg/ha/yr (Henzell and Ross, 1973). However, in a tropical study Henzell and Norris (1962) reported values of about this magnitude for total N. The reason for the high Ca values is not known. The samples did not appear to have been contiminated, and no lime was observed to have been applied in the area, which would be a possible explanation. However, Golley (1975) reported an average value of 29 Kg/ha/yr for Ca applied by rainfall in a tropical moist forest. The values for P, K, and Mg appear to be in line with those reported by Ewel et al. (1975).

The assumption that the animals used in this study were returning all minerals consumed is reasonable since they were not gaining weight (Chapter 10). A normal healthy cow will urinate an average of nine times and deficate 12 to 18 times in a 24 hour period (Hafez, 1969). The length

of time food material remains in the stomach is about 48 hours (Hungate, 1966). It is expected that the material ejected during the first two days on the study site is representative of the holding pasture rather than the study site. Since this pasture was a better area (bahiagrass), the average values given for nutrients ontained in the fecal material would be higher than would be expected if the animals were only on the study site. The estimated values given for the increments of minerals to the site based only on mineral intake may therefore be lower than what really occurred, due to the difference in forage quality between the two sites.

The failure to find meaningful differences between the pastures receiving a high increase in P to the foliar P content, is believed due to the length of time it requires P to move into the soil profile (Chapter 12). It is doubtful, considering the high variations of foliar P content observed in Chapter 8, that any increase would be noted in a one year study.

The significance of mineral supplementation to a nutrient-poor flatwoods site is not to be underrated since it is entirely possible that in three years the mineral input of P may equal that found in the top 30 cm of soil. On a P deficient area this is bound to cause a change in the community structure, unrelated to other grazing factors, much the same as applying P to the site as fertilizer. The response to P on flatwoods have been noted by other investigators (Pritchett and Gooding, 1975; White and Pritchett, 1970). Hilmon and Douglas (1967), in a study of forest fertilization in Georgia, reported that wiregrass showed a poor response but the bluegrasses and Panicums showed a significant response. Since the more desirable grasses respond to fertilizer better than wiregrass, fertilization via mineral supplementation may result in a change of species composition over time.

Energy, protein, and P are the three main items that limit the use of flatwoods range for use by wildlife and livestock (Chapter 10). The use of these areas by dry cows, properly supplemented, would inhance the overall fertility of the site over time. It is suggested that the Ca:P ratio in the mineral be reversed, i.e. a 1:2 ratio. This would be a first step in an overall management program aimed at improving the range condition of the site. Graze a flatwoods area for five to ten years prior to implementing other improvement practices. This would allow (under proper management) forages that require a higher plane of nutrition to become established, thereby reducing the amount of improvement, and the cost, that would be applied later. An experiment designed to test this contention should be high on the priority list.

CHAPTER 14

NUTRIENT SIMULATION MODEL

Introduction

A system is defined as a limited portion of reality, with the boundaries chosen so that the environment influences the system but not vice versa (DeWit and Goudriaan, 1974). A model is an abstraction and/or simplification of a system. Obviously, it cannot have all the attributes of a real system, or it would cease to be a model (Hall and Day, 1977). Since systems change with time (dynamic), a simplified representation of a dynamic system is a dynamic model. Simulation is defined as the building of a dynamic model and the study of its behavior (DeWit and Goudriaan, 1974). In constructing a model the problem lies in knowing what to leave out. The components omitted must be of the kind that do not perform key or dominant roles in the system being investigated. With editing most systems can be reduced to a few basics and the model will still predict the main responses of the system (Hall and Day, 1977).

Numerous models have been developed for various agricultural systems, most of which employ methods of linear programming. Cook et al. (1977) suggest the use of the computer optimization planning system (COPLAN) in determining the least cost basis for use of rangelands. The range resource allocation method (RAM) is a planning method designed to help range planners and managers to develop and evaluate intermediate and long-term proposals (Jansen, 1977); as well as various economics and management models (Jameson et al., 1974; Beneke and Winterboer, 1973; Loewer et al., 1978).

Before simulation a model must be conceptualized. This may be nothing more than a block and arrow diagram, where state variables are placed in the boxes and flows are represented by arrows, or more sophisticated forms, such as systems languages. The energy circuit language was developed by H. T. Odum (1971; 1972; Odum and Odum, 1976) to aid in visualizing relations and to combine energetics, kinetics, and economics. This "energese" methodology has been used to evaluate and predict numerous ecosystems in Florida and elsewhere. Of particular interest are those models simulating pasture systems in Florida. DeBellevue et al. (1975) and Gutierrez (1978) simulated generalized pasture systems in South Florida; Gutierrez et al. (1975) looked at a pasture system near Lake Okeechobee as affecting eutrophication of the lake. Range systems, per se, were not simulated by these models.

The purpose of this study is to model the nutrient cycling of P in a Florida flatwoods with cattle.

A generalized description of mineral cycles was presented in Chapter 4. Phosphorus has an incomplete cycle due to its low concentration in the atmosphere (Deevey, 1970). It is of interest in this investigation since it is believed to be the major nutrient limiting plant and animal growth in the Florida flatwoods (Chapter 4). Black (1968) reported soil P values of less than 0.017% in the southeastern Coastal Plains.

Phosphorus cycling is determined by its low mobility in soils and relative stability. Under normal soil conditions of an oxidizing atmosphere and normal pH ranges it is not subject to large losses by leaching or volatilization (Black, 1968). Gaseous losses are apparently confined to anaerobic conditions with an abundance of decomposable organic matter (Alexander, 1964). Phosphorus cycling is, therefore, accomplished through the plant and animal components of the ecosystem (Wilkinson and Lowery, 1973).

Movement of P in the system follows several paths such as through the grazing animal (believed to increase the turnover rate, Grant and French, 1975). The generally recognized cycle is from the plant to litter through the decomposer into the soil and back to the plant. Losses from the system take the form of leaching from the plant material and subsequent loss through surface runoff. Phosphorus has been found to be leached from frozen or dead plant parts by water, with values of 69 to 80% of the total P being removed by water and presumably entering the soil profile (Wilkinson and Lowery, 1973). Timmons et al. (1970) found that leaching of P from fresh cut grass was quite small but increased significantly when the material had been frozen first. On an area that was subjected to high surface runoffs this could pose a serious loss to the system, especially during the winter months. However, visual observations at the study site indicate that even with intense rains, surface runoff was virtually absent, due to the high porosity of the sandy soils. Other leaching losses are by percolation through the soil and out of the system through the ground water. Since the P content in soil solutions is generally less than 0.1 ppm (Black, 1968), and P content of the ground water taken from the study site averaged less than 0.05 ppm (Chapter 4). Losses from the flatwoods system are believed to be low.

Atmospheric inputs are estimated to be 0.75 Kg/ha/yr (Chapter 13) and while small by most standards, on the P deficient soils of the flatwoods, may represent a significant input. Phosphorus return through fecal decomposition is generally believed to occur over approximately 12% of the land area per year, covering 94% of the area in a ten year period (Petersen et al., 1956a). However, this does not consider coprophagous insects and their effect in increasing the distribution of fecal material over a wide area (Bornemissza and Gillare, 1967). The flatwoods contained dung beetles, but the extent of their activity was not ascertained.

It is assumed that over a period of time the distribution of P on a grazed pasture will be uniform. The basis for this assumption lies in the numerous mechanisms that are known or suspected to be operating on this site; lateral flow, insects, movement of plant material by animals, litter fall, fire, etc.

The soil P content was found to be the major factor in a simulation of P cycling in a semiarid grassland in the Western United States and Canada (Cole et al., 1977). For this and reasons discussed in other chapters, the flatwoods soils, and the low P content contained are believed to be the most significant factors in this nutrient cycling study.

Of particular interest is the role of mineral supplementation to the dominant grazer (cattle) and the effect of redistribution through feces to the plant community. Also of interest is the effect of grazing on the plants themselves and the competitive effect of the different categories of plants (grazables and ungrazables) on each other.

Materials and Methods

The "energese" language (H. Odum, 1972) was used to construct the basic model. This language was translated to analog circuitry by methods of H. Odum (1978)[12]. The analog computer used was the MiniAc, analog/hybrid computing system, manufactured by Electronics Associates, Inc.

The basic energy and P model of the flatwoods system are presented in Figures 14.1. and 14.2., respectively. Definitions of the major energese language symbols are given in Appendix G. This model shows various pathways of energy flow throughout the system with cattle, timber, and understory plants as major components. Heat sinks, representing loss of energy, occur at each point of energy transformation. The basic cycle of the system is assumed

12. Odum, H. T. 1978. Systems Ecology, class syllabus.

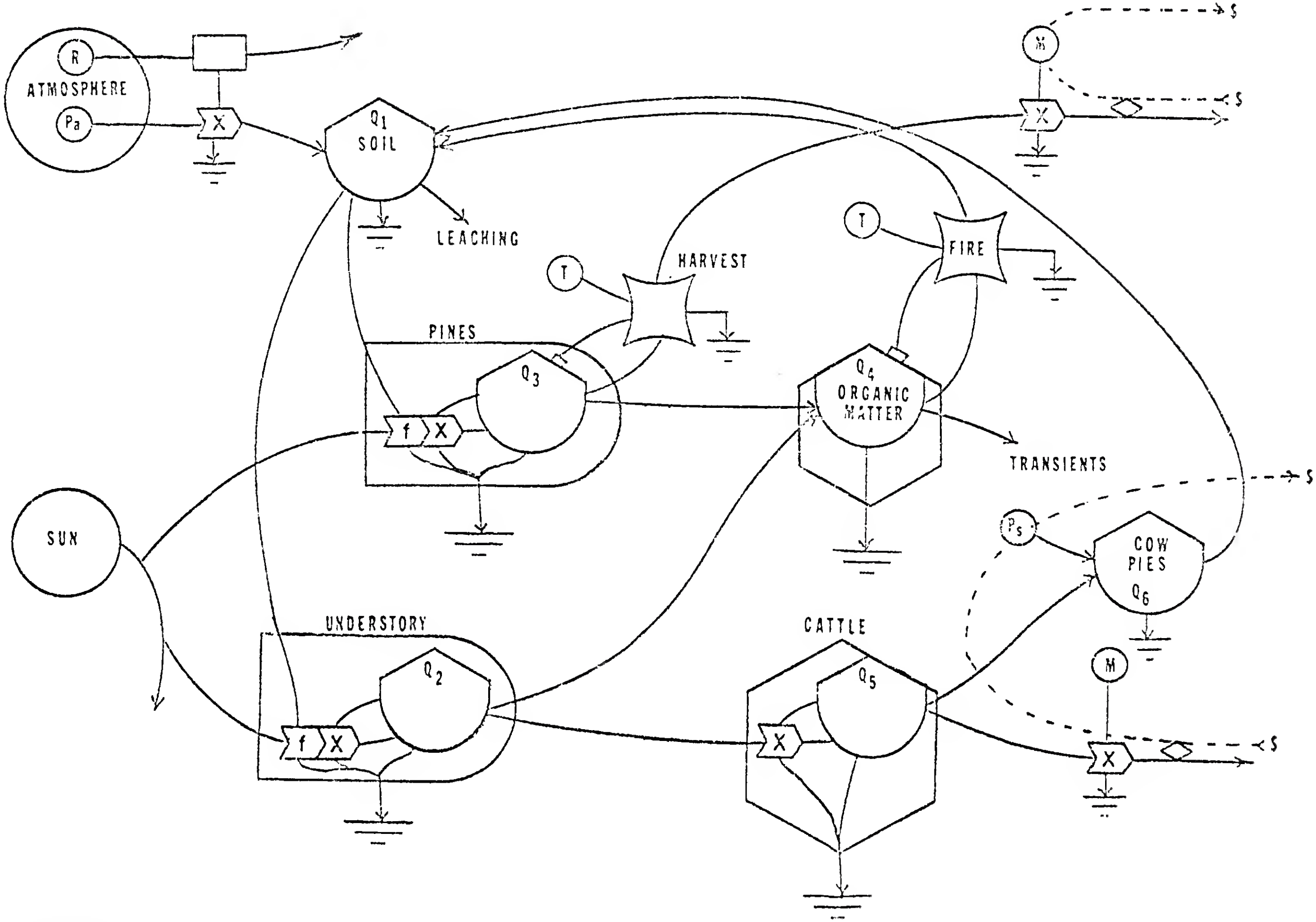

Figure 14.1. Energy model of grazed flatwoods system.

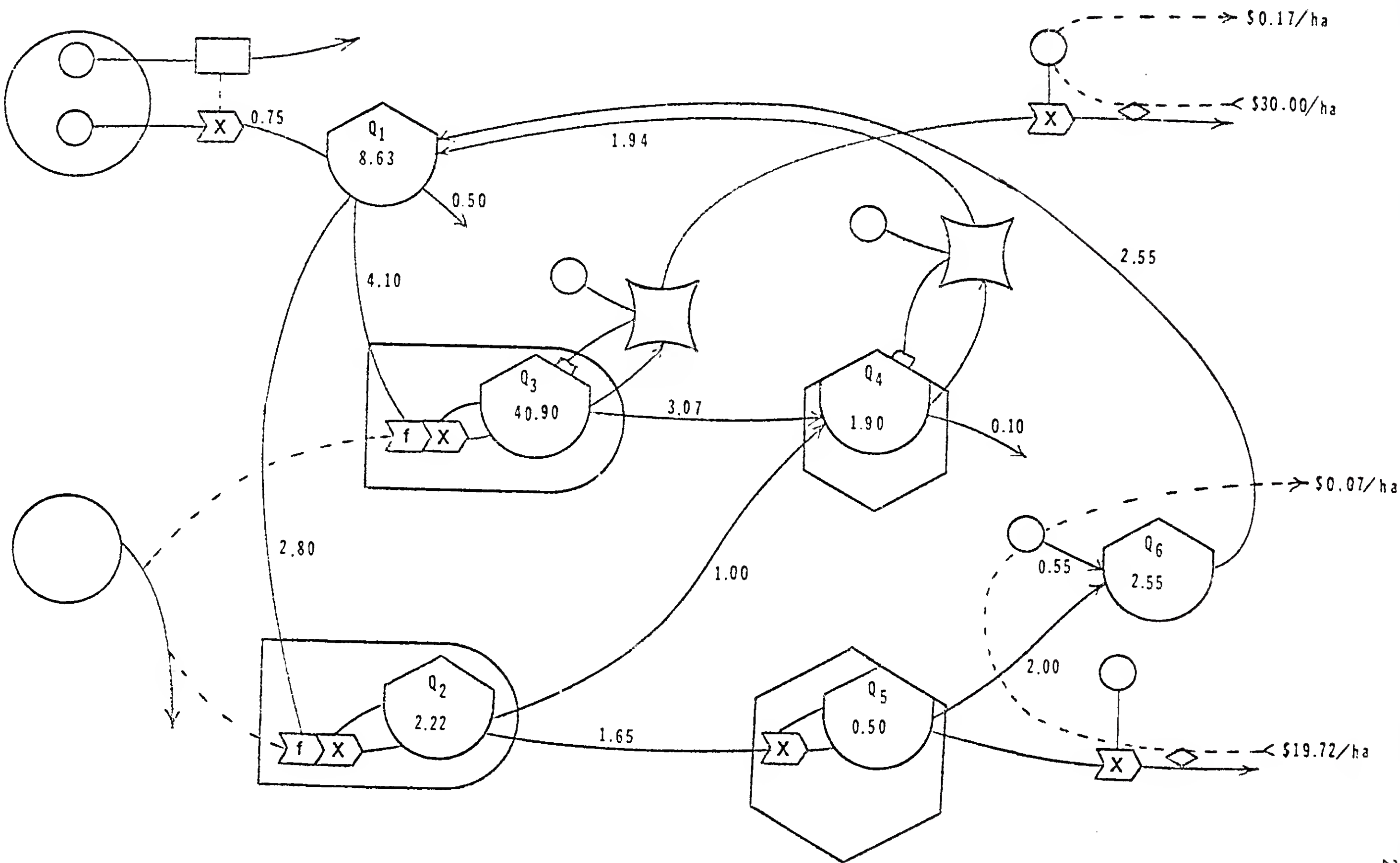

Figure 14.2. Phosphorus flows in the grazed flatwoods system.

to occur at 35 year intervals with the harvest of the timber (Q_3). Fire is included in the schematic as occurring every three to five years, and is dependent upon the content of the organic matter tank (Q_4). This fire cycle will not be included in the actual simulation, a constant rate of removal per year is assumed.

Figures 14.2. is a model of the P cycle for the timber/cattle system showing P flows. Energy (sunlight) drives this system but does not contribute P. Rainfall acts as a force bringing in P from the atmosphere. The numbers contained in the storage compartments and on the pathways are based upon field measurements or estimations from the literature and are expressed as Kg/ha or Kg/ha/yr, respectively (Table 14.1.).

The ungrazed biomass of the site is primarily P. palustris. The average number of trees on the site is 230 per hectare, with an average diameter of 27.9 cm. Based on regression equations from Conde et al. (1978)[13] biomass of pine trees in terms of foliage, stems and branches were obtained as a function of diameter. Data from White and Pritchett (1970) and Pritchett and Smith (1974) were then utilized to calculate the amount of P in the above ground tree biomass (40.86 Kg/ha). Based upon 50% utilization, the P content of the grazed plants (Q_2) was determined to be 1.11 Kg/ha. This value was also added to that of the trees for a total of 41.97 Kg/ha in the ungrazed compartment (Q_3). The flow from the soil to the pines was based on the P content in the needles (the length of needle retention is approximately one year on this site), and the amount stored as wood (based on 42 cord harvest every 35 years).

The amount of P in the soil (Q_1) was from data reported in Chapter 4, replication IV, two-month rest. The amount of P in cattle was assumed to be

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13. Conde, L., B. Swindle, and J. Smith. 1978. Sch. of For. Res. and Consv., Univ. Fla., Unpublished data.

Table 14.1. Definitions of symbols and equations used in simulation model.

State variables

Q_1	phosphorus content in soil
Q_2	phosphorus content in understory
Q_3	phosphorus content in overstory (pines)
Q_4	phosphorus content in organic matter (litter)
Q_5	phosphorus content in cattle
Q_6	phosphorus content in cow pies

Sources in Kg/ha

Pa	atmospheric input of phosphorus, constant (Chapter 13)
R	rainfall, constant = 138 cm/yr (Chapter 13)
Sun	sunlight, constant = 3.65×10^9 (estimated)
P_S	phosphorus supplement to cattle (Chapter 13)
M	marketing (estimated)

Energy flows

$k_1J_oQ_1Q_3 = 2.00 \times 10^9$ Kcal/ha/yr (estimated based on 55% canopy cover, Chapter 9)

$k_2J_oQ_1Q_3 = 1.65 \times 10^9$ Kcal/ha/yr (estimated based on 55% canopy cover, Chapter 9)

Phosphorus flows in Kg/ha/yr

$k_3P_aQ_1 = 0.75$ (Chapter 13)

$k_4Q_1 = 0.50$ (Chapter 4, and Black, 1968)

$k_5Q_1Q_2 = 2.80$ (estimated based on % P in understory and production, (Chapters 8 and 9)

$k_6Q_1Q_3 = 4.10$ (estimated, based on biomass of pine, % P contained, litter fall, amount stored as wood, Chapter 14)

$k_7Q_2Q_5 = 1.65$ (based on production and 50% utilization, Chapter 10)

$k_8Q_3Q_4 = 3.07$ (based on amount of litter fall, Chapter 9)

$k_9Q_2Q_4 = 1.00$ (based on production, less amount consumed by cattle and retained as structure, Chapters 9 and 10)

$k_{10}Q_4 = 0.10$ (estimated loss to transients)

$k_{11}Q_4 = 1.94$ (based on 74%/yr decomposition rate for plants and 40%/yr for pines, Chapter 12 and Pritchett, 1976)

Table 14.1. - continued

$k_{12}Q_5M = 0.12$ (based on 60% calf crop, and 160 Kg calves, Chapter 14)

$k_{13}Q_6P_s = 0.55$ (Chapter 13)

$k_{14}Q_5Q_6 = 2.00$ (Chapter 10)

$k_{15}Q_6Q_1 = 2.55$ (based on 111%/yr decomposition, Chapter 12)

Equations

$$\dot{Q}_1 = k_3P_aQ_1 + k_{11}Q_4 + k_{15}Q_1Q_6 - k_6Q_1Q_3 - k_5Q_1Q_2 - k_4Q_1 \quad (8)$$

$$\dot{Q}_2 = k_5Q_1Q_2 - k_7Q_2Q_5 - k_9Q_2Q_4 \quad (9)$$

$$\dot{Q}_3 = k_6Q_1Q_3 - k_8Q_3Q_4 \quad (10)$$

$$\dot{Q}_4 = k_8Q_3Q_4 + k_9Q_2Q_4 - k_{10}Q_4 - k_{11}Q_4 \quad (11)$$

$$\dot{Q}_5 = k_7Q_2Q_5 - k_{12}Q_5M - k_{14}Q_5Q_6 \quad (12)$$

$$\dot{Q}_6 = k_{14}Q_5Q_6 + k_{13}Q_6P_s - k_{15}Q_1Q_6 \quad (13)$$

0.74% of liveweight (Maynard and Loosli, 1969). This value was adjusted to the carrying capacity of 0.3 cows per hectare, for a 400 Kg animal. The amount lost to market (M) was based on a 60% calf crop with an average weight of 160 Kg per calf and computed on a per hectare basis for the above carrying capacity.

For the purpose of this model all P is assumed to pass through the animal. In actual practice only 90 to 95% of the P passes through (Petersen et al. 1956b; Heady, 1975), the balance accumulating in the various organs. All P is considered to be deposited in feces (only 4% is voided in urine, Petersen et al. 1956b). The animals consume 0.18 Kg/day of mineral supplement containing 5% P. This results in a consumption of 0.55 Kg/ha/yr, based on stocking rate of one cow per six hectares. The amount of P ingested in the forage is 1.65 Kg/ha/yr (Chapters 8, 9, and 10). Fecal output was from Chapter 10, based on the P content of cow pies (Chapter 13), is assumed to contain 2 Kg/ha/yr of P. All P values given for cattle were adjusted to a per hectare basis by dividing by the stocking rate. The flows from the organic matter and the cow pie compartments were based on the rate of decomposition (Chapter 12), 74% for plants and 111% for excreta.

The P uptake of the grazed compartment (Q_2) was estimated based on the amount of forage consumed by cattle and the residual. Data from Heyward and Barnett (1936) were used to determine the percent P (0.047) in the litter under a P. palustris canopy. With the average litter production data from replication IV (4032 Kg/ha), the P content was calculated to be 1.90 Kg/ha for the organic matter compartment (Q_4). It was assumed that P leached from the plant and fecal material at a linear rate. Loss of P from the soil was also assumed to be a linear function and was based on ground water sampling (Chapter 4). Energy from the sun was 3.65×10^9 Kcal/ha/yr; this is the energy available at canopy level, after all losses have been removed. Rainfall

and atmospheric input of P were taken to be constant at 138 cm and 0.74 Kg/ha/yr, respectively (Chapter 13). Loss of P to transient herbivores was unknown and an estimated value (0.1 Kg/ha) was used.

Economic data was based on 1978 conditions. Calves from flatwoods ranges are assumed to grade good and are valued at \$1.32/Kg (\$60.00/cwt). A cord of wood, for pulp, on the stump was assumed to be \$25.00. The cost of 5% P mineral supplement for cattle was \$120/908 Kg (\$120/ton). The cost of P fertilizer was 22¢/Kg with an application cost of \$2.50/ha. Money flows are depicted from the sale of timber and calves and costs are for the P supplement for the cattle and fertilizer required to replace that lost by sale of timber.

Basic data in Figure 14.2. was used in the model simulation. Solar radiation was partitioned so that the overstory (trees) received it first and the understory second. Since firm field data was lacking for some of the initial parameters (Table 14.1.), the results of the simulation are not quantified, but are presented as trends.

Once the model was operational specific experiments were conducted. Initial soil levels were increased by two and four times the initial values (fertilization) and effects with and without trees and/or cattle were observed. The P input to the initial system from both atmospheric and mineral supplement to the cattle were varied and effects noted, both with and without trees and/or cattle. The trees were harvested and results of this loss of P to the system with and without cattle noted. The rates of loss of P from the initial system were varied as well as the decomposition rates for plant and fecal material, and the effects observed.

Results

From data presented in Figure 14.2. the soil compartment (Q_1) has a net loss of 0.68 Kg/ha/yr. This loss is primarily due to the increment of P that is being stored in the pine compartment (Q_3), with eventual loss to the system through sale of timber. The understory (Q_2) shows a slight increase (0.15 Kg/ha/yr) which, under the existing stand, is to be expected. This is because certain plants (e.g. gallberry) which are not grazed and are fire tolerant are increasing in biomass. Under a regular pine plantation these plants would be eliminated shortly after canopy closure.

The pines (Q_3) show an increase of 1.03 Kg/ha/yr of P. This is stored and removed every 35 years, in effect representing a drain on the available P, unless replaced through fertilization. The organic matter tank (Q_4) is shown as having no change. In actual practice this tank would build up until a fire, then drain to near zero. If fire was excluded from the system this tank would build up until approximately 12 years and remain relatively stable thereafter, with decomposition equalling litter fall.

The cattle compartment indicates a modest rate of increase (0.08 Kg/ha/yr). In actual practice this would represent the accumulation of P in the mature cow and would be removed at the end of her reproductive life (approximately 12 years) through marketing. The cow pie compartment (Q_6) has a zero change. This is due to the high rate of decomposition (111%/yr) with no carry over from one year to the next.

If cattle are removed the timber system has essentially the same values for the plant compartments as the timber-cattle system. The major difference lies in the higher return of P to the soil from the decomposition of the organic matter (litter). With fire the inputs to the soil tank would be the same as in the timber-cattle system. Without fire there would be an increase to about

12 years. This buildup would slow down the growth of pines during the first few years, since P is accumulated in the litter layer and is not available for growth. However, if the initial soil reserves were large enough, this might not hinder growth too much, if some kind of understory suppression was practiced. With fire, P would return to the soil where it would be available, also the understory would be held in check, thus preventing eventual takeover by the hardwoods.

Economic evaluation of the system based on Figure 14.2. indicates that the timber-cattle system has the greatest net income after the cost of P supplements to the system are removed. On a 35 year cycle the sale of calves represents about \$690/ha and the sale of 42 cords of wood represents \$1050/ha. The total cost of maintaining P in the system is \$8.50/ha per 35 years. With timber alone the dollar income is the same, but the cost of maintaining the P level has increased to \$9.20/ha/cycle. If cattle are removed from the system the cost of P fertilization, to replace that lost to harvest, increases from 17 cents to 26 cents per year. Without cattle the amount of salable timber is expected to remain about the same, or decrease due to the increased turnover time of that portion of the plant biomass not passing through cattle (111%/yr compared to 74% without cattle).

Table 14.1. lists the initial conditions (with sources) and the equations and coefficients used in the simulation. The actual model simulated is presented in Figure 14.3. depicting the association of equations from Table 14.1.

With the initial conditions as calculated the model did not reach steady state. The main reason was that the soil P compartment (Q_1) exceeded the assumed maximum value assigned it. This was rectified by increasing the drain (k_4) on the soil tank (Q_1); steady state was then reached in approximately 120 years. The time scale was then shifted to 35 years, and minor modifications

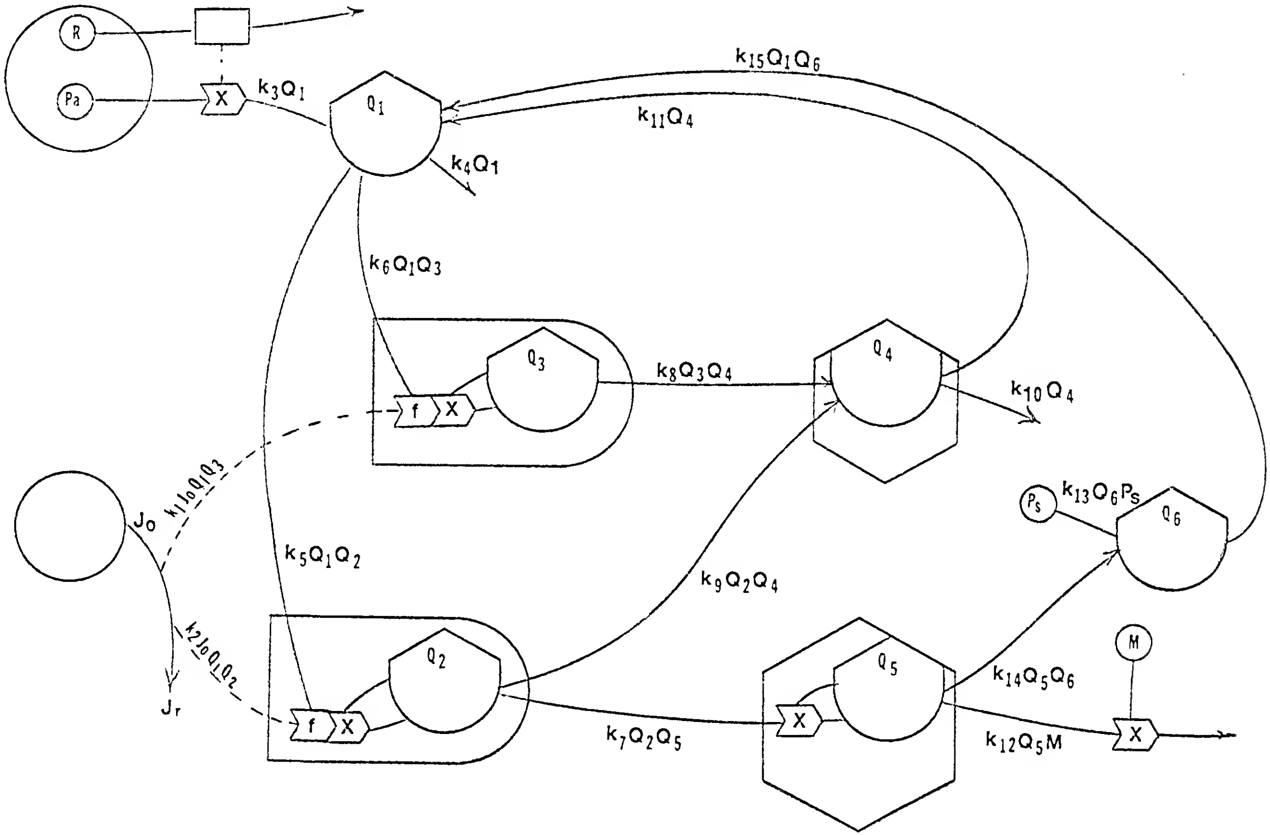


Figure 14.3. Simulated model with equations.

were made to the cow pie (Q_6) and the organic matter (Q_4) tanks to allow them to reach a steady state condition in a time period that was believed to be realistic in an actual managed system.

The performance of the four compartments of interest (Q_1, Q_2, Q_3, and Q_5) are depicted in Figure 14.4. The pines (Q_3) show a near linear rate of growth, the soils (Q_1) reach a peak in about 14 years, the understory (Q_2) peaks at about two years and then decline. Cattle (Q_5) lag the understory and reach maximum values (about 50% increase) five years later. This is an artifact of the program which allows cattle to increase at a natural rate, and does not allow for the introduction of new cattle as would be the case in a man-operated system. The cow pie and the organic matter tank were manipulated to reach steady state in approximately two and three years, respectively, thus implying a fire dominated system.

Cattle (with all inputs and outputs relating to them) were removed from the system. This resulted in the understory having a slightly higher growth rate persisting until approximately the 28th year. The pines showed a slight decrease initially, then increased toward the end of the cycle. Next the trees were removed (harvested) and the cattle were taken off, and a new cycle begun. This resulted in the soil compartment reaching near zero levels in about ten years. The understory doubled in four years then decreased to near zero at about 20 years. The pines showed evidence of some buildup, starting at about the 30th year (Figure 14.5.). This particular scenario was sensitive to the loss rate from the soil (k_4), decreasing the rate by half resulted in 50% increase in the understory, and the pines increased noticeably.

Initial conditions were then reset and P was added to the soil compartment at the beginning of the cycle (twice initial levels) with and without cattle. Results of these simulations are presented with cattle (Figure 14.6.) and without cattle (Figure 14.7.). All components in both of these simulations

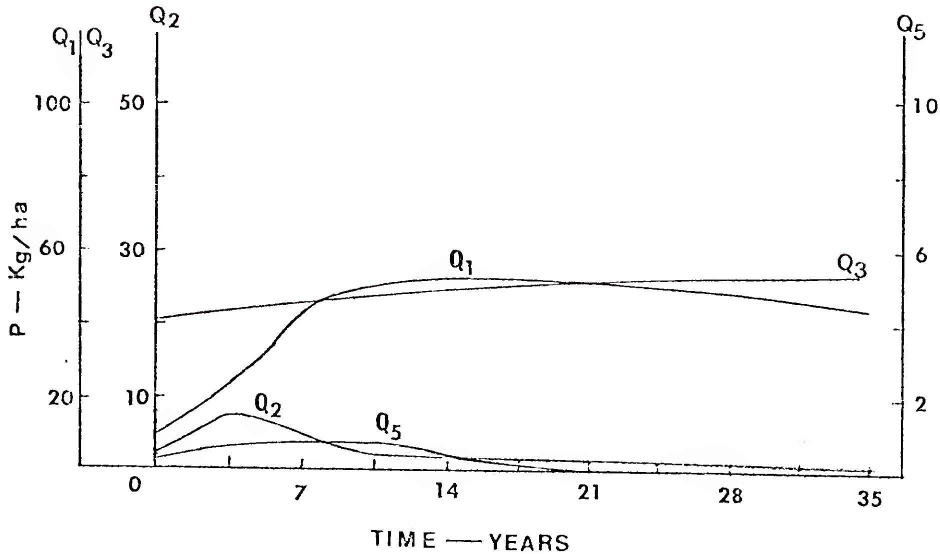


Figure 14.4. Performance of the soil (Q_1), understory (Q_2), pines (Q_3), and cattle (Q_5) as a function of time (initial conditions).

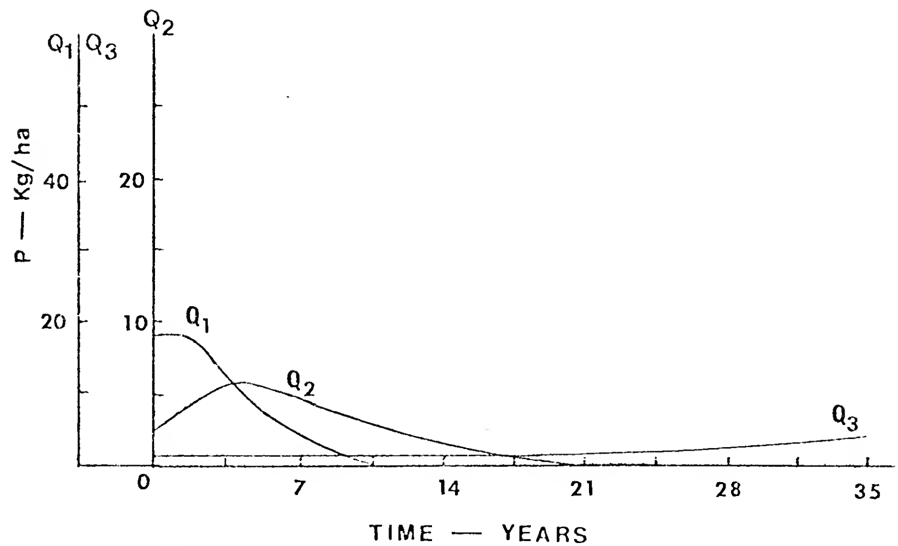


Figure 14.5. Effect of harvesting trees, without cattle, on the soil and understory (initial conditions).

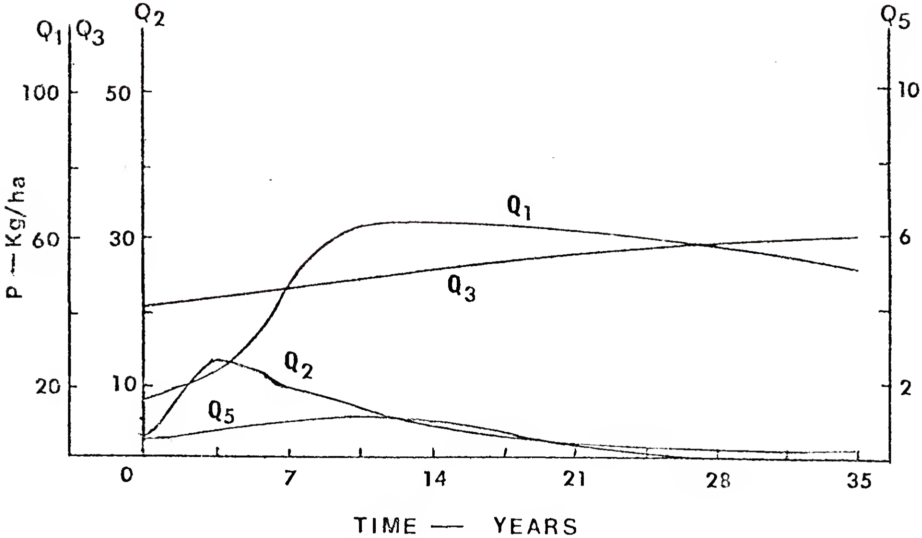


Figure 14.6. Twice initial soil phosphorus level, with cattle.

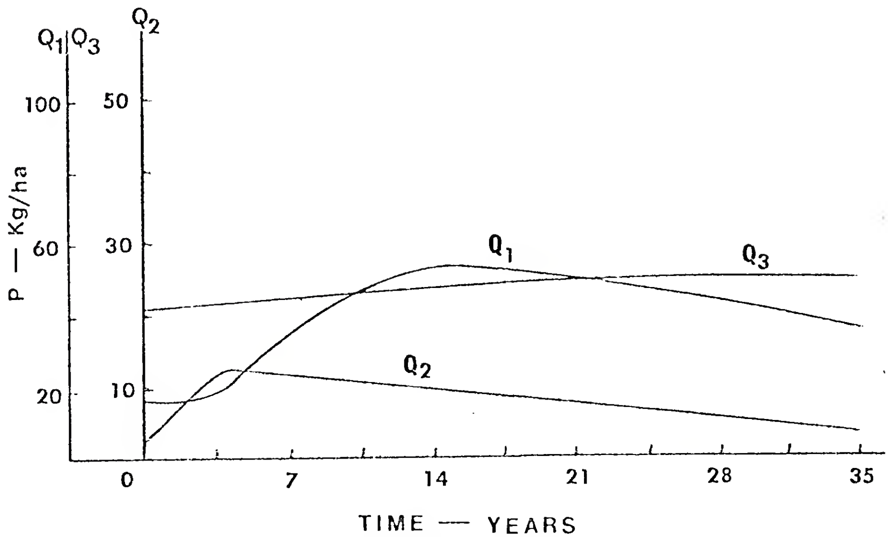


Figure 14.7. Twice initial soil phosphorus level, without cattle.

increased over the initial run (Figure 14.4.). When the level of fertilization was increased to four times the initial soil conditions a fourfold increase in the cattle compartment was noted compared to when the soil P level was doubled Figure 14.8.); the understory and pines doubled their growth.

The final experiment involved the initial conditions, except that P was added in the cattle mineral supplement equal to the initial soil level for each year (Figure 14.9.). This resulted in the understory doubling in size over the initial conditions (Figure 14.4.) and remaining at this level for over ten years; the cattle increased five times over the initial run.

The effects of competition of the pines on the understory is noted by the decline of the understory in the simulation without cattle (Figure 14.7.). The understory reaches a peak, and is responsible for the dip in the soil P curve, this is reflected in the slight decrease in growth of the pines at the same time (approximately at two years). Because the main driving force (sunlight) passes through the overstory first, and the understory gets only that portion not used by the pines, the pines win out in the end. Similar effects are noted when cattle are introduced to the system, when the cattle reach a peak, the understory increases its rate of decrease.

Discussion and Conclusions

The analysis of the phosphorus model demonstrates that unless P is added to the system the site can be expected to deteriorate. Pritchett (1976) has commented upon this aspect of site deterioration in noting that second growth pines do not do as well as first growth, unless fertilized. This particular site is similar to much of Florida in that it has been logged twice, perhaps three times. It is highly suspected that the removal of P from the system in the form of pulpwood is responsible for the poor nutrient quality of the site. If the pines were harvested, assuming initial rates of atmospheric input and

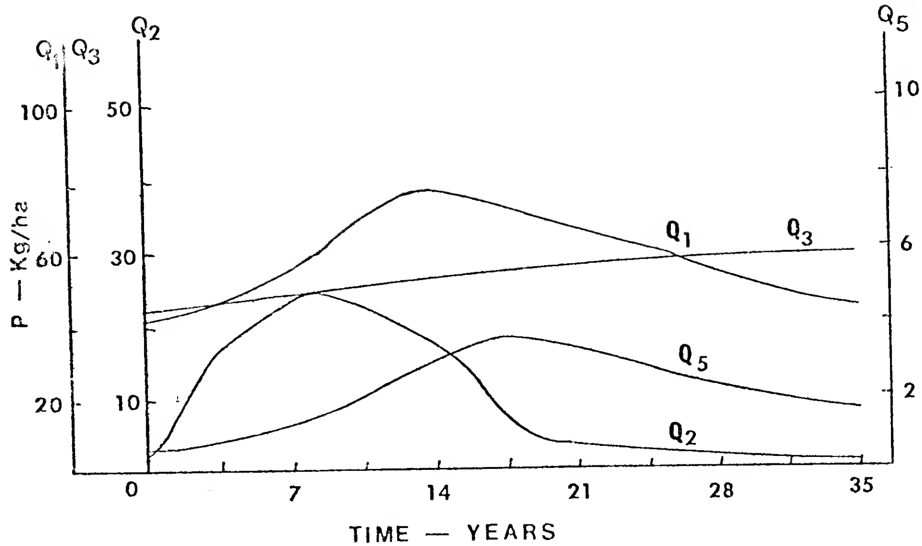


Figure 14.8. Soil phosphorus level four times initial value.

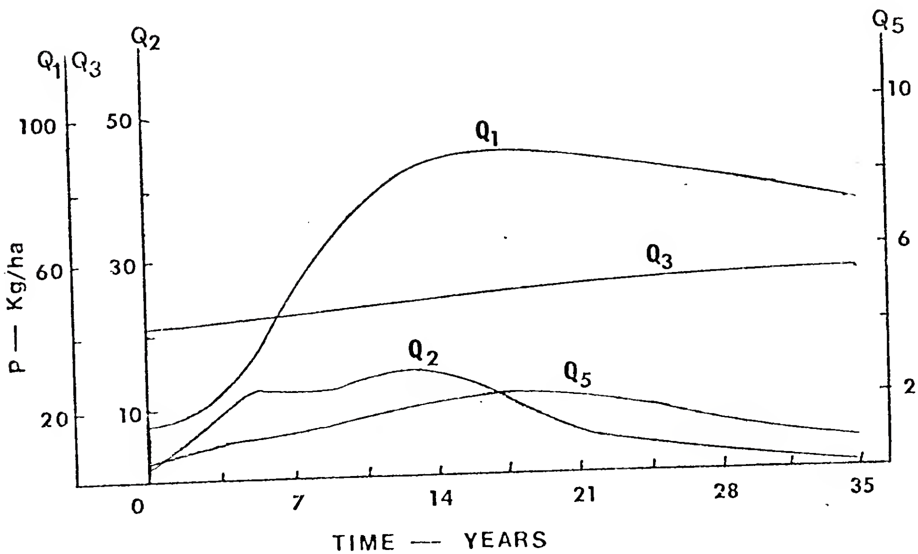


Figure 14.9. Initial conditions, phosphorus input to cattle equal to initial soil value.

leaching loss, 144 years would be required to return this site to the original level of P, assuming no loss by transient herbivores. If the area is grazed by supplemented cattle at the 5% P level, then 53 years would be required to restore the site. If the recommendations suggested in Chapters 13 and 15 regarding increasing the P level to 10% in the mineral supplement to cattle, then only 30 years would be required. The 30 year cycle would match the 35 year harvest and would allow for some improvement in the stored soil P. The cost of fertilization would be borne by the cattle enterprise and the timber would benefit from it.

The economic analysis based on P only, clearly demonstrates the feasibility of running cattle on natural stands of pines. There are numerous other costs associated with running cattle, mineral supplementation is only one small portion. Anderson and Hipp (1974),from an economic study of beef herds on Florida flatwoods soils, reported a positive annual return to land and management from cattle run on the range, $16.57 per head or $2.76 per hectare based on six hectares per cow. With a return of $2.76/ha the cattle portion would contribute $96.66 in 35 years. These values are based on 1971 data when calves were low in value compared to current 1978 prices. This return, while low compared to the sale of timber, would in all probability meet the land tax.

Extrapolating the results of a native system to a pine plantation system presents some difficulties. The turnaround time on a plantation system is 20 to 25 years. The trees are usually fertilized at planting which results in increased production to both the pines and the understory. Canopy closure is usually reached between 10 and 15 years. This would limit the time that livestock could graze the area, since when the canopy closes the understory dies off. An investigation of this type of system should be conducted.

Results of the simulations suggest that fertilization of the site is a necessity, if any meaningful production is to be obtained. Fertilization may

be accomplished either through direct application or through cattle. If P is added through the cattle, larger yearly quantities are needed than if direct application is used. This is because of the delay associated with decomposition and also from the spotty nature of deposition.

The model pointed out areas of needed research, which are the rate of loss and uptake of P from native systems. It was believed that the loss rate was low, based on water samples and from the literature (Black, 1968; Rodulfo and Blue, 1970). This may well be the case, especially when low soil levels are involved. The system would then approximate some tropical systems where the nutrients are conserved in the biomass and not in the soil. However, the failure of the model to stabilize with a low leaching rate, suggest that either the loss rates are too low or the uptake by the plants is higher than estimated, or both. The determination of the rates of P loss from a native flatwoods system would enable better P fertilization schedules to be set up with amounts adjusted to obtain maximum utilization of the plant community.

Recommendations from this study are that cattle should be run on native pine flatwoods ranges. The cattle should be supplemented with 10% P, in addition the range should be fertilized with P at a rate double the amount removed from the sale of timber. The result of this type of program would bring the system back to pre-white man conditions. Forage quality and species composition would be expected to change toward the more desirable species for grazing. Growth of both trees and understory would be enhanced, resulting in earlier turnover times for the timber, or larger trees if the same cycle was retained, and increased forage yields, hence greater animal production.

CHAPTER 15

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This investigation did not result in data that would lend itself to drawing firm conclusions concerning management alternatives. However, there were sufficient trends that, coupled with this investigator's practical background, allow some management suggestions to be made. In addition, numerous areas of promising research were uncovered, both of a practical and basic nature.

The BRU is not a unique flatwoods, it was selected as typifying the flatwoods of central Florida (Killinger, 1960). The flatwoods comprise over 50% of the land area of the state and are generally low in all nutrients, except silica, with P being the most crucial. Calcium and K appear to be present in low, but generally adequate, amounts. Nitrogen may be a problem for certain groups of plants, but pines are apparently more P limited (Pritchett, 1968). The foliar concentrations of Ca are adequate for nutritional requirements during the year for both wildlife and livestock. Phosphorus content in native forages is generally low with respect to animal maintenance requirements and may also be low for optimal plant growth. Energy appears to be limited for livestock at the 50% level of available forage utilization.

The ability of cattle to select needed forages has not been lost in domestic cattle (Chapter 11). The Ca:P ratio in the native forages is high, 5:1 for the forages that comprised the cattle diets (Chapter 10). The ability of cattle and presumably other wildlife to select forages with a low Ca:P

ratio would somewhat negate this high ratio observed in clipped forages. However, because the bulk of the native forages appear to have high ratios, a 30 to 40% utilization of the native forages, as suggested by Halls (1956) is recommended for flatwoods ranges. The 50% utilization of native ranges, as now practiced, should be discouraged in Florida.

In Chapter 13 it was suggested that the Ca:P ratio in mineral mix supplied to range cattle be adjusted to a 1:2 ratio. This ratio would offset the high ratio that exists in the native range plants. By reducing the overall diet Ca:P ratio to levels approaching the recommended values (2:1 - 1:1, Maynard and Loosli, 1969) more efficient utilization of the range would be achieved. Animals would be selecting plants for other factors rather than a low Ca:P ratio.

Small pastures tend to magnify the effects of local soil variability and also prohibit the animals from seeking those areas where plants rich in needed nutrients may be growing. Future range studies should utilize large pastures, at least ten hectares in size to more adequately evaluate different methods of grazing. If possible, the pastures should be selected to contain as many different soil types as feasible. A lesson can be learned from the old-time method of curing salt-sick (Chapter 2). Experimental designs should be a Latin square, factorial or perhaps a response surface, since there is a high variability associated with native ranges. Preliminary analysis should be made to determine the soil and forage variability prior to determining sample size. Since forage quality is dependent upon site fertility, studies should also report soil nutrient levels, especially P and N, also Al and Fe as Al and Fe determine the amount of P available to plants. Methods of handling soil samples should be standardized and the procedures reported.

Brahman or Brahman-crossed cattle are to be preferred over English breeds. For a range operation rigid selection for high performance cattle is a must.

Native forage quality would dictate that the range areas be utilized by dry cows properly supplemented with P and energy. Since most herds calve in the early spring this would imply that the range use should occur in the fall and winter, times when quality of the range is at its lowest for most species. Based on Halls (1956) recommendations and the analysis of forages it is suggested that if the degree of utilization is reduced to 30%, dry cows and yearlings in the spring and fall (if a fall flush is noted) could utilize the range flatwoods if properly supplemented. Mother cows may also do well but only if rigorous selection is practiced.

The conclusions reached by Felts (1976) and Young (1977) concerning their recommendations of a 4 month rest in a high intensity-short duration grazing system are not substantiated by this investigation. The fact that the 6 month rest pastures were grazed in this and in the previous two studies during the dormant periods of plant growth (winter and mid-summer), does not test the effectiveness of the 6 month rest treatment, and invalidates this aspect of the experiment. The small pasture size used in these investigations resulted in local soil variability significantly influencing the data, since the experimental design did not allow within treatment effects to be removed. Also, one year is not a long enough time to allow specific recommendations to be made on the effectiveness of a grazing system, especially when they are conducted in a period of extreme weather variability such as existed in 1976 and 1977.

Management objectives determine the optimal level of use in a grazing system. If the objective is to obtain a higher level of nutrients in the foliage of pine trees, and by inference, a higher growth rate of trees, then heavy grazing of the understory is indicated. If the objectives is the production of wildlife food, then some other intensity is called for (no significant trends were evident from this study but some light to moderate grazing

utilization did appear to be indicated). If cattle production is the goal there is a strong suspicion that from three to four months is the best length of rest to use in a short duration-high intensity grazing system. However, this could be modified by determination of the proper percentage of utilization of the available forage.

A larger experiment is called for, one using larger pastures and/or more replications, employing an experimental design which will allow for more variations. The duration should be five years and the length of rest should be selected such that they are not cyclic from one year to the next (ie. falling on the same date each year).

There is some evidence that if a flatwoods is grazed for a period of years by properly supplemented (minerals) animals, the nutrient content of the site will increase, particularly with respect to P. Hilmon and Douglas (1967) found that the more desirable grasses responded better to fertilizers than did wiregrass. This increased nutrient content and a possible change in species composition would reduce the cost of range improvements. This would be accomplished by having the range in better condition prior to the improvement practice, with a consequent increased probability of obtaining the desired results. It is not presently known what percentage of the range animals are being supplied with a mineralized supplement. If past practices of Florida cattlemen are any indication, it is probably low (Chapter 2). Supplementing range cattle would benefit the range, the cattle, and any incidental wildlife, and is highly recommended.

Mineral supplementation of cattle in the Florida flatwoods is an area in which considerable effort needs to be directed. If the hypotheses concerning mineral supplementation of cattle results in improvement of the forage quality of plants and allows more efficient utilization are correct, there are implications for wildlife management people as well as livestock producers. Deer

react to quality forage the same as livestock. It is not inconceivable that the quantity and quality of the Florida deer herd would be improved by supplementation practices.

The following are areas of promising research:

1. Test the hypothesis of mineral supplementation improving site quality.
2. Determine digestibility and nutrient content of important range species over all seasons of the year and on different sites.
3. Determine year round diet selections for both livestock and deer, with particular reference to energy requirements and the Ca:P ratio.
4. Set up grazing trials to determine proper percent of utilization of available forage for range flatwoods.
5. Set up grazing trials to determine the effectiveness of the short duration-high intensity grazing system under Florida conditions.
6. Test the hypothesis that grazing stimulates pines to increased growth, with and without mineral supplementation.
7. Test the hypothesis that range adapted animals are better able to digest range forages.
8. Test effect of different Ca:P ratios on cattle grazing a range area.
9. Determine if site fertility is related to age of the standing timber and the amount lost to the site by harvest.
10. Verify that Brahman or Brahman-crossed animals are better adapted for range conditions.

11. Determine optimum foliar nutrient levels in range plants and the effects of fertilization on the digestibility and nutrient content of these plants.
12. Test the hypothesis that Arthropods may be consuming as much if not more of the herbage than the larger grazing herbivores.
13. Determine if high soil variability is the norm in flatwoods and if this variability is correlated with foliar nutrient concentrations. Further test other soil types to see if this is unique to sandy soils or is more general in nature.
14. Test Halls (1955) canopy cover theory to determine the amount of variability under Florida conditions.
15. Determine rates of nutrient turnover of a grazed and ungrazed system and test the hypothesis that herbivores increase the rate of turnover.
16. Test to see if the coefficient of variation (CV) can be used to determine limiting factors by measuring the amount of variability of foliar nutrient levels in natural systems.
17. Test the hypothesis that lateral water movement in small elevations cause, or is responsible in part, for the high variability noted in flatwoods sites.
18. Test the hypothesis that herbivores select for C_3 plants, and if so, the degree of selection and what, if any, implications this has on the herbivore population in the state.
19. Investigate the effects of Ca on the *in vitro* procedure.

APPENDIX A

SITE AND METHODS DATA

APPENDIX A

Table A. 1. Dates of sampling, herbage weights (Kg/ha), based on regression equations, percent of each pasture classified as moist (M), wet (W), and dry (D).

Site type	Before cattle entry Sampling Date	Before cattle entry % of area	Before cattle entry Herbage Wt. (Kg/ha)	After cattle entry Sampling Date	After cattle entry % of area	After cattle entry Herbage Wt.(Kg/ha)
			2 month rest - replication I			
M	7/7/76	90.0	1719.8	7/22/76	100.0	1155.1
W		7.5	99.0		-	-
D		2.5	32.3		-	-
Total			1851.1			1155.1
M	9/19/76	97.5	1321.7	9/30/76	97.5	1307.5
W		-	-		-	-
D		2.5	40.2		2.5	328
Total			1361.9			1340.3
M	11/8/76	95.0	842.2	11/19/76	95.0	438.6
W		-	-		-	-
D		5.0	68.5		5.0	64.5
Total			910.7			503.1
M	2/7/77	100.0	830.7	3/8/77	100.0	406.5
W		-	-		-	-
D		-	-		-	-
Total			830.7			406.5
M	4/6/77	97.5	1107.8	4/27/77	92.5	897.2
W		-	-		-	-
D		2.5	19.2		7.5	64.5
Total			1127.0			961.7

Table A. 1. - continued

Site type	Before cattle entry Sampling date	% of area	Herbage wt. (Kg/ha)	After cattle entry Sampling date	% of area	Herbage wt. (Kg/ha)
M	6/16/77	100.0	1389.5	7/6/77	100.0	1147.8
W		-	-		-	-
D		-	-		-	-
Total			1389.5			1147.8
M	8/31/77	100.0	1380.1	9/21/77	95.0	1729.7
W		-	-		-	-
D		-	-		5.0	74.7
Total			1380.1			1804.4
2 month rest - replication II						
M	6/29/76	100.0	2213.2	7/17/76	100.0	1250.0
W		-	-		-	-
D		-	-		-	-
Total			2213.2			1250.0
M	9/10/76	90.0	2216.9	9/29/76	90.0	1523.2
W		-	-		-	-
D		10.0	138.7		10.0	121.7
Total			2355.6			1644.9
M	11/5/76	90.0	895.1	11/18/76	90.0	814.6
W		-	-		-	-
D		10.0	105.8		10.0	101.8
Total			1000.9			916.4
M	1/27/77	100.0	629.8	3/8/77	97.5	610.8
W		-	-		-	-
D		-	-		2.5	17.0
Total			629.8			627.8

Table A. 1. - continued

Site type	Before cattle entry: Sampling Date	Before cattle entry: % of area	Before cattle entry: Herbage wt. (Kg/ha)	After cattle entry: Sampling date	After cattle entry: % of area	After cattle entry: Herbage wt. (Kg/ha)
M	4/6/77	92.5	1070.5	4/25/77	85.0	680.0
W		-	-		-	-
D		7.5	70.7		15.0	173.7
Total			1141.2			853.7
M	6/16/77	95.0	1305.8	6/22/77	95.0	1238.5
W		-	-		-	-
D		5.0	42.4		5.0	58.3
Total			1348.2			1296.8
M	8/28/77	97.5	2120.3	9/12/77	95.0	1520.2
W		-	-		-	-
D		2.5	44.7		5.0	74.1
Total			2165.0			1594.3
			2 month rest - replication III			
M	6/29/76	100.0	1629.7	7/17/76	100.0	1587.4
W		-	-		-	-
D		-	-		-	-
Total			1629.7			1587.4
M	9/10/76	87.5	1376.0	9/27/76	87.5	1131.1
W		-	-		-	-
D		12.5	186.9		12.5	152.5
Total			1562.9			1283.6
M	11/4/76	87.5	981.8	11/18/76	87.5	975.8
W		-	-		-	-
D		12.5	135.0		12.5	127.7
Total			1116.8			1103.5

Table A. 1. - continued

Site type	Before cattle entry: Sampling date	Before cattle entry: % of area	Before cattle entry: Herbage wt. (Kg/ha)	After cattle entry: Sampling date	After cattle entry: % of area	After cattle entry: Herbage wt. (Kg/ha)
M	1/27/77	100.0	565.7	3/8/77	100.0	501.2
W		-	-		-	-
D		-	-		-	-
Total			565.7			501.2
M	4/6/77	97.5	1118.4	4/25/77	95.0	826.0
W		-	-		-	-
D		2.5	14.6		5.0	40.8
Total			1133.0			866.8
M	6/16/77	92.5	1803.2	6/28/77	95.0	1086.4
W		-	-		-	-
D		7.5	88.3		5.0	38.6
Total			1891.5			1125.0
M	8/28/77	92.5	1540.1	9/12/77	87.5	1188.6
W		5.0	66.6		7.5	18.4
D		2.5	50.4		5.0	46.0
Total			1657.1			1253.0
2 month rest - replication IV						
M	7/6/76	82.5	1983.0	7/23/76	100.0	1192.6
W		17.5	390.4		-	-
D		-	-		-	-
Total			2473.4			1192.6
M	9/20/76	82.5	1292.0	9/30/76	77.5	1466.5
W		12.5	348.8		17.5	394.2
D		5.0	83.2		5.0	49.8
Total			1724.0			1910.5

Table A. 1. - continued

Site type	Before cattle entry Sampling date	% of area	Herbage wt. (Kg/ha)	After cattle entry Sampling date	% of area	Herbage wt. (Kg/ha)
M	11/8/76	82.5	894.0	11/18/76	82.5	763.2
W		12.5	140.4		12.5	151.9
D		5.0	31.5		5.0	36.6
Total			1065.9			951.7
M	2/7/77	100.0	653.8	3/8/77	100.0	718.4
W		-	-		-	-
D		-	-		-	-
Total			653.8			718.4
M	4/7/77	92.5	1299.8	4/27/77	90.0	898.0
W		7.5	96.0		10.0	135.9
D		-	-		-	-
Total			1395.8			1033.9
M	6/21/77	82.5	1235.4	7/6/77	90.0	1421.1
W		15.0	214.0		10.0	194.5
D		2.5	33.0		-	-
Total			1515.4			1615.6
M	9/1/77	87.5	1430.6	9/21/77	90.0	1213.7
W		12.5	301.8		10.0	163.8
D		-	-		-	-
Total			1732.4			1377.5
			4 month rest - replication I			
M	8/9/76	55.0	2079.9	8/27/76	55.0	1227.1
W		40.0	1055.1		45.0	635.6
D		5.0	91.9		-	-
Total			3226.9			1862.7

Table A. 1. - continued

Site type	Before cattle entry: Sampling date	% of area	Herbage wt. (Kg/ha)	After cattle entry: Sampling date	% of area	Herbage wt. (Kg/ha)
M	12/9/76	70.0	868.3	2/11/77	97.5	1201.2
W		30.0	305.6		2.5	55.9
D		-	-		-	-
Total			1173.9			1257.1
M	4/20/77	60.0	1105.9	5/12/77	67.5	1225.9
W		40.0	535.7		32.5	158.4
D		-	-		-	-
Total			1641.6			1384.3
M	8/22/77	50.0	1685.6	9/12/77	57.5	1653.5
W		50.0	1051.5		42.5	602.6
D		--	-		-	-
Total			2737.1			2256.1
4 month rest - replication II						
M	8/5/76	55.0	979.1	8/25/76	75.0	1467.0
W		30.0	417.8		22.5	323.2
D		15.0	224.6		2.5	28.8
Total			1621.5			1819.0
M	12/8/76	95.0	1497.2	1/24/77	90.0	1034.0
W		5.0	13.7		10.0	112.2
D		-	-		-	-
Total			1510.9			1146.2
M	4/18/77	80.0	1358.4	5/10/77	87.5	1273.8
W		5.0	61.3		5.0	61.7
D		15.0	191.8		7.5	86.0
Total			1611.5			1421.5

Table A. 1. - continued

Site type	Before cattle entry			After cattle entry		
	Sampling date	% of area	Herbage wt. (Kg/ha)	Sampling date	% of area	Herbage wt. (Kg/ha)
M	8/16/77	72.5	1691.8	8/28/77	67.5	1514.8
W		20.0	329.2		25.0	404.6
D		7.5	130.2		7.5	115.5
Total			2151.2			2034.9
4 month rest - replication III						
M	8/2/76	92.5	1099.9	8/19/76	87.5	878.0
W		5.0	74.6		10.0	76.3
D		2.5	31.7		2.5	10.7
Total			1174.5			965.0
M	12/8/76	92.5	967.0	2/17/77	97.5	481.2
W		5.0	11.2		2.5	19.8
D		2.5	6.5		-	-
Total			978.2			501.0
M	4/18/77	95.0	665.2	5/5/77	97.5	439.6
W		5.0	23.8		2.5	1.5
D		-	-		-	-
Total			689.0			441.1
M	8/16/77	85.0	994.9	8/31/77	92.5	981.3
W		15.0	157.5		7.5	69.3
D		-	-		-	-
Total			1152.4			1050.6

Table A. 1. - continued

Site type	Before cattle entry: Sampling date	% of area	Herbage wt. (Kg/ha)	After cattle entry: Sampling date	% of area	Herbage wt. (Kg/ha)
			4 month rest - replication IV			
M	8/9/76	70.0	2282.9	8/19/76	70.0	1850.1
W		22.5	610.6		25.0	603.5
D		7.5	93.2		5.0	54.0
Total			2986.7			2507.6
M	12/9/76	72.5	1214.1	1/24/77	70.0	908.9
W		27.5	548.2		30.0	542.0
D		-	-		-	-
Total			1762.3			1450.9
M	4/20/77	82.5	1531.3	5/11/77	82.5	1477.3
W		12.5	210.5		10.0	205.1
D		5.0	48.8		7.5	70.6
Total			1790.6			1753.0
M	8/22/77	67.5	1888.9	9/12/77	85.0	2012.3
W		32.5	817.7		15.0	364.9
D		-	-		-	-
Total			2706.6			2377.2
			6 month rest - replication I			
M	7/26/76	65.0	1923.5	8/19/76	75.0	1738.0
W		27.5	568.1		20.0	505.9
D		7.5	158.3		5.0	107.9
Total			2649.9			2351.5

Table A. 1. - continued

Site type	Before cattle entry Sampling date	% of area	Herbage wt. (Kg/ha)	After cattle entry Sampling date	% of area	Herbage wt. (Kg/ha)
M	1/13/77	90.0	1717.8	3/1/77	100.0	1219.1
W		7.5	150.2		-	-
D		2.5	20.4		-	-
Total			1888.4			1219.1
M	7/14/77	77.5	1604.3	8/1/77	60.0	1693.2
W		20.0	511.3		32.5	530.3
D		2.5	56.6		7.5	115.5
Total			2172.2			2339.0
6 month rest - replication II						
M	7/19/76	85.0	1548.3	7/29/76	72.5	1444.8
W		7.5	180.9		27.5	405.8
D		7.5	130.8		-	-
Total			1860.0			1850.6
M	1/10/77	95.0	1305.6	2/16/77	100.0	1087.9
W		5.0	111.9		-	-
D		-	-		-	-
Total			1417.5			1087.9
M	7/8/77	92.5	1779.6	7/18/77	75.0	2049.5
W		7.5	142.1		22.5	269.4
D		-	-		2.5	65.1
Total			1921.7			2382.0

Table A. 1. - continued

Site type	Before cattle entry: Sampling date	Before cattle entry: % of area	Before cattle entry: Herbage wt. (Kg/ha)	After cattle entry: Sampling date	After cattle entry: % of area	After cattle entry: Herbage wt. (Kg/ha)
			6 month rest - replication III			
M	7/19/76	90.0	959.1	7/30/76	77.5	769.4
W		-	-		-	-
D		10.0	60.8		22.5	181.4
Total			1019.9			950.8
M	1/7/77	75.0	436.4	2/16/77	82.5	229.2
W		-	-		-	-
D		25.0	96.7		17.5	62.5
Total			533.1			291.7
M	7/8/77	70.0	788.7	7/18/77	67.5	662.4
W		-	-		-	-
D		30.0	216.5		32.5	201.9
Total			1005.2			864.3
			6 month rest - replication IV			
M	7/27/76	85.0	2509.3	8/19/76	97.5	2646.7
W		-	-		-	-
D		15.0	360.9		2.5	74.5
Total			2870.2			2721.2
M	1/12/77	87.5	921.6	3/1/77	92.5	912.5
W		-	-		-	-
D		12.5	178.7		7.5	40.2
Total			1100.3			952.7
M	7/14/77	77.5	2486.0	8/1/77	85.0	1765.3
W		-	-		-	-
D		22.5	434.8		15.0	197.0
Total			2920.8			1962.3

Table A. 1. - continued

Site type	Sampling date	% of area	Herbage wt. (Kg/ha)	Sampling date	% of area	Herbage wt. (Kg/ha)
	12 month rest - replication			12 month rest - replication II		
M	7/12/76	80.0	1353.1	8/26/76	90.0	2191.6
W		20.0	191.2		5.0	74.1
D		-	-		5.0	103.3
Total			1544.3			2369.0
M	10/7/76	67.5	1151.5	10/7/76	95.0	2083.8
W		32.5	344.0		5.0	70.5
D		-	-		-	-
Total			1495.5			2154.3
M	11/19/76	65.0	838.9	11/23/76	95.0	1619.0
W		35.0	588.2		5.0	94.1
D		-	-		-	-
Total			1427.1			1713.1
M	3/15/77	100.0	1032.0	3/11/77	100.0	1430.1
W		-	-		-	-
D		-	-		-	-
Total			1032.0			1430.1
M	5/18/77	85.0	1031.2	5/17/77	95.0	1375.6
W		15.0	96.0		5.0	63.6
D		-	-		-	-
Total			1127.2			1439.2
M	7/6/66	80.0	1399.9	8/23/77	92.5	2053.2
W		20.0	233.4		5.0	70.2
D		-	-		2.5	34.0
Total			1633.3			2157.4

Table A. 1. - continued

Site type	Sampling date	% of area	Herbage wt. (Kg/ha)	Sampling date	% of area	Herbage wt. (Kg/ha)
M	9/14/77	72.5	1204.9	9/13/77	87.5	1820.1
W		27.5	583.1		7.5	274.1
D		-	-		5.0	118.3
Total			1788.0			2212.5
	12 month rest - replication III			12 month rest - replication IV		
M	7/12/76	87.5	603.8	8/26/76	67.5	2327.6
W		-	-		30.0	395.2
D		12.5	154.2		2.5	68.5
Total			758.0			2791.3
M	10/6/76	70.0	682.0	10/1/76	57.5	1614.7
W		-	-		27.5	792.9
D		30.0	472.0		15.0	445.3
Total			1154.0			2852.9
M	11/19/76	70.0	518.8	11/23/76	75.0	990.7
W		-	-		17.5	275.1
D		30.0	183.6		7.5	137.6
Total			702.4			1403.4
M	3/15/77	85.0	259.8	3/11/77	85.0	1249.3
W		-	-		10.0	168.6
D		15.0	69.1		5.0	52.8
Total			328.9			1470.7
M	5/18/77	82.5	602.7	5/17/77	72.5	1304.9
W		5.0	8.1		20.0	197.3
D		12.5	91.9		7.5	89.9
Total			702.7			1592.1

Table A. 1. - continued

Site type	Sampling date	% of area	Herbage wt. (Kg/ha)	Sampling date	% of area	Herbage wt. (Kg/ha)
M	7/1/77	72.5	548.5	6/24/77	67.5	1350.0
W		-	-		25.0	751.4
D		27.5	194.6		7.5	118.2
Total			743.1			2219.6
M	9/14/77	70.0	530.5	9/13/77	72.5	2177.8
W		-	-		25.0	691.2
D		30.0	299.1		2.5	45.1
Total			829.6			2914.1

Table A. 2. Common names of trees and shrubs found at the study site.

Scientific name[1]	Common name	Habitat type	Primary herbivore
Trees			
Acer rubrum (L)	Red maple	M	D, I, L
Disopyros virginiana (L)	Persimmon	M	I, D
Pinus elliottii (Engelm)	Slash pine	M	I, D, L
Pinus palustris (Miller)	Longleaf pine	M-D	I, D,L
Quercus geminata (Small)	Sand live oak	D	I, D, L
Quercus incana (Bartram)	Bluejack oak	D	I, D, L
Quercus nigra (L)	Water oak	M	I, D, L
Quercus myrtifolia (Willd)	Myrtle oak	D	I, D, L
Shrubs			
Asimina longifolia (Adanson)	Pawpaw	M-D	I
Callicarpa americana (L)	American beautyberry	M	D, L
Chrysobalanus oblongifolius (Michaux)	Gopher apple	M-D	I, D
Gaylussacia dumosa (Andra)	Dwarf huckleberry	M	I, L, D
Ilex coriacea (Pursh)	Large gallberry	M	D, I
Ilex glabra (L)	Gallberry	M	D, I, L
Kalmia hirsuta (Walter)	Laurel	M	D, I
Lyonia lucida (LAM)	Fetterbush	M	D, I
Myrica cerifera (L)	Wax myrtle	M	D, I
Quercus pumila (Walter)	Runner oak	D-M	I, D, L
Rhus copallina (L)	Shining sumac	M	D, I
Rubus spp. (L)	Blackberry	M	D, L, I
Serenoa repens (Bartram)	Saw palmetto	W-M	L, D, I
Sorbus arbutifolia (L)	Chokeberry	M	I, D, L
Stillingia sylvatica (Garden)	Queens delight	M-D	I, D
Vaccinium arboreaum (Marshall)	Sparkleberry	M	D, I
Vaccinium myrsinites (LAM)	Ground blueberry	M	D, I, L
		W = Wet M = Moist D = Dry	D = Deer L = Livestock I = Insect

1. Authority for scientific names: Radford et al. 1968.

Table A. 3. Common names of legumes, forbs, and miscellaneous plants found at the study site.

Scientific name[1]	Common name	Habitat type	Primary Herbivore
Legumes			
Cassia nictitans (L)	Partridge pea	W-M	L, I
Centrosema spp. (Bentham)	Butterfly pea	M-D	L, I
Crotalaria spp. (L)	Crotalaria	M	I, L
Desmodium spp. (Desvaux)	Beggarweed	M	I, L
Galactia spp. (Browne)	Milk pea	M-D	I, L, D
Lespedeza spp. (Michaux)	Lespedeza	M-D	I, L, D
Rhynchosia spp. (Lour.)	Dollar weed	M-D	L, D, I
Tephrosia spp. (Persoon)	Goats-rue	M-D	I, L
Forbs			
Ambrosia artemisifolia (L)	Ragweed	M-D	I
Cirsium carolinianum (Walter)	Purple thistle	D	I
Centella asiatica (L)	Pennywort	W-M	D, L
Diodia teres (Walter)	Poor Joe	M-D	I, D
Elephantopus tomentosus (L)	Elephants foot	M-D	D, I, L
Erynigium yuccifolium (Michaux)	Bear grass	M	I, L
Euphorbia spp. (L)	Spurge	M	I
Heterothecia graminifolia (Michaux)	Grassy leaf golden aster	M-D	L, I
Hypericum spp. (L)	St. Johns wort	M-D	I
Lactuca floridana (Gaertner)	Wild lettuce	M	I
Lippia nodiflora (Michaux)	Creeping charlie	M-D	I
Pteridium aquilinum (Kuhn)	Bracken fern	M	I, D
Pterocaulon pycnostachyum (Michaux)	Rabbit tobacco	M	D, I
Rhexia mariana (L)	Meadow beauty	W-M	I
Solanum carolinense (L)	Bull nettle	M-D	I
Tradescantia spp. (L)	Spider wort	M-D	I
Trilisa paniculata (Walter)	Deer tongue	W-M	D, I
Woodwardia virginica (Smith)	Chain fern	M	D, I
Xyris ambigua (Beyrich)	Yellow eyed grass	W-M	D, I

1. Authority for scientific names: Radford et al. 1968.

Table A. 3. - continued

Misc.			
Gelsemium sempervirens (Alton)	Yellow jassamine	M-D	D, I
Smilax auriculata (Walter)	Greenbriar	M-D	L, D, I
Tillandsia usenoides (L)	Spanish moss	W-M	L, D
Vitus rotundifolia (Michaux)	Wild grape	M	D, L

Table A. 4. Common names and characteristics of range grasses at the study site.

Scientific name[1]	Common name	Metabolic Pathway	Warm or Cool season	Habitat type	Primary herbivore
Grasses					
Amphicarpum muhlenbergianum (Schultes)	Blue maidencane	C_4 (2)	W	W-M	L, D
Andropogon capilippes (Nash)	Chalky bluestem	C_4 (?)	W	W	L
Andropogon virginicus (L)	Broomsedge	C_4 (1)	W	M-D	L
Anthaentia villosa (Michaux)	Green silky scale	C_4 (?)	W	D	L
Aristida stricta (Michaux)	Pineland threeawn	C_4 (?)	C	M	L, D
Axonopus affinis (Chase)	Carpetgrass	C_4 (1)	W	M-W	L
Ctenium aromaticum (Walter)	Toothache grass	C_4 (?)	W	W	L
Digitaria villosa (Walter)	Shaggy fingergrass	C_4 (1)	W	M	L
Erogrostis spectabilis (Pursh)	Purple love grass	C_4 (2)	W	M	L
Eremochloa ophioroides (Munro)	Centipede grass	C_4 (?)	W	D	L
Panicum aciculare (Desv.)	Needleleaf	C_3 (2)	W	M-D	L, D, B
Panicum anceps (Michaux)	Beaked panicum	C_4 (1)	W	M-W	L, D, B
Panicum hemitomon (Schult)	Maidencane	C_4 (2)	W	W-M	L
Paspalum notatum (Flügge)	Bahia grass	C_4 (1)	C	M	L
Paspalum setaceum (Michaux)	Thin pasplum	C_4 (2)	W	W-M	L
Schyizachyrium stolonifer (Nash)	Creeping bluestem	C_4 (?)	W	M	L
Setaria geniculata (Lam)	Knotroot bristlegrass	C_4 (2)	W	W-M	L, B
Sorghastrum nutans (Nash)	Indian grass	C_4 (1)	W	M	L
Sporobolus curtissii (Vasey)	Curtis dropseed	C_4 (2)	C	M	L
Sporobolus junceus (Michaux)	Pineywoods dropseed	C_4 (2)	W	D	L, D
Triplasis americana (Beaux)	Sand grass	C_4 (2)	C	D	L, B
Grasslikes[2]					
Hypoxis spp. (L)	Hypoxis	-	-	M-D	I
Scleria mulhenbergia (Steudel)	Annual razor sedge	-	-	D	I, D, L

Authority for scientific names:
1. Radford et al. (1968)
2. Hitchcock (1950)

(1) = Downton (1975)
(2) = Teeri and Stowe (1976)
(?) = Suspected - based on genus and growth habits.

L = Livestock
D = Deer
B = Birds
I = Insects

Table A. 5. 1976 and 1977 monthly total rainfall and average minimum and maximum temperatures for the BRU and the 70 year averages for Gainesville.

Month	1976			1977			Gainesville 70 Yr. Avg.		
	Precip. (ins.)	Temperatures Min. °F	Max. °F	Precip. (ins.)	Temperatures Min. °F	Max. °F	Precip. (ins.)	Temperatures Min. °F	Max. °F
Jan.	2.10	35.2	65.0	2.69	33.1	58.6	2.84	46.9	68.5
Feb.	1.33	42.0	74.7	3.29	35.4	65.8	3.70	48.0	70.8
Mar.	1.80	52.3	81.0	1.45	52.7	79.4	4.26	52.8	76.0
April	3.02	51.8	81.9	0.48	52.2	82.5	3.02	57.7	81.7
May	5.55	60.0	85.3	3.06	58.0	89.5	3.54	63.6	87.4
Jun.	8.45	65.4	88.7	3.32	66.9	95.8	6.81	69.2	90.3
Jul.	2.01	68.8	94.0	6.51	68.1	94.8	8.03	71.0	90.6
Aug.	3.92	67.8	91.9	5.14	69.9	91.9	8.25	71.3	90.0
Sep.	9.08	66.2	88.2	6.79	68.9	91.2	5.67	69.4	88.7
Oct.	2.16	51.5	78.8	0.52	52.5	80.5	3.68	61.3	82.6
Nov.	2.21	42.0	69.4	2.22	50.9	76.4	1.92	51.6	76.6
Dec.	4.97	39.4	64.6	4.39	39.8	66.1	2.93	46.7	69.0
Total Precip.	46.60			39.86			54.65		
Avg. Yrly. Mean Temp.		66.9			67.5			70.1	

APPENDIX B

DESCRIPTION OF SOILS FOUND ON STUDY SITE

Adamsville Series

The Adamsville series is a memeber of the hyperthermic, uncoated family of Aquic Quartzipsamments. These are sandy soils having grayish A horizons and mottled grayish or brownish C horizons.

Typifying Pedon: Adamsville fine sand - range.
(Colors are for moist soil unless otherwise stated.)

A11 - 0-6" - Dark gray (10YR 4/1) fine sand; weak fine crumb structure; friable; many fine, medium and course roots; mixture of organic matter and light gray sand grains having salt-and-pepper appearance; medium acid; clear smooth boundary. (4 to 8 inches thick)

A12 - 6-12" - Dark grayish brown (10 YR 4/2) fine sand; single grained; loose; common fine medium and coarse roots; sand grains uncoated; medium acid; gradual wavy boundary. (0 - 12 inches thick)

C1 - 12-22" - Grayish brown (10YR 5/2) fine sand; many fine and medium faint, very dark grayish brown, light brownish gray, and pale brown mottles; singel grained, loose; common fine roots; many uncoated sand grains; slightly acid; gradual wavy boundary. (4 to 24 inches thick)

C2 - 22-28" - Very pale brown (10YR 7/4) fine sand; common medium and coarse faint brownish yellow (10YR 6/6) mottles; single grained; loose sand grains well coated in mottled parts,

uncoated in matrix; slightly acid; gradual wavy boundary. (6 to 18 inches thick)

C3 - 28-42" - White (10YR 8/2) fine sand; few medium to coarse distinct olive brown (2.5Y 5/4) mottles; single grained; compact in place, loose when crushed; sand grains in matrix uncoated; few large pockets of loamy sand in lower 2 inches of the horizon; mildly alkaline; clear smooth boundary. (10 to 24 inches thick)

C4 - 42-72" - Light gray (10YR 7/1), grading to light brownish gray (10YR 6/2) in lower part, fine sand; few medium faint light brownish gray and grayish brown mottles; single grained; loose; mildly alkaline.

Type location: Okeechobee County, Florida; 1-½ miles west of intersection of U.S. 441 and Old Dixie Highway, and 100 feet south in NE1/sec. 29, T. 37 S., R. 35E.

Range in Characteristics: Mean annual soil temperature at depths of 20 inches below the surface is 72° to 74°F. Soil reaction ranges from very strongly acid through mildly alkaline. Texture of the soil is sand or fine sand to depths of 80 inches or more. Silt plus clay content is less than 5 percent in the 10- to 40-inch control section. The A horizons are black (10YR 2/1, N 2/) very dark gray (10YR 3/1, N 3/), very dark grayish brown (10Yr 3/2), dark gray (10YR 4/1, N 4/), dark grayish brown (10YR 4/2), gray (10YR 5/1, N 5/) or grayish brown (10YR 5/2). Black (10YR 2/1, N 2/), very dark gray (10YR 3/1, N 3/), or very dark grayish brown (10YR 3/2) A horizons are less than 10 inches thick. The C horizon is gray (10YR 5/1, 6/1, N 5/, N 6/), grayish brown (10YR 5/2), light brownish gray (10YR 6/2), light gray (10YR 7/1, 7/2, N 7/), white (10YR 8/1, 8/2, N 8/), very pale brown (10YR

7/3, 7/4), pale brown (10YR 6/3), yellowish brown (10YR 5/4), or brown (10YR 5/3). This horizon has mottles in shades of gray, yellow, and brown. In some pedons mottles are lacking. Matrix colors are due to uncoated sand grains or thin coatings of organic matter.

Setting: Adamsville soils are on low, broad flats in lower Coastal Plains. Slopes are generally less than 2 percent. The regolith is thick beds of sand marine sediments. Mean annual precipitation is 50 or more inches and mean annual air temperature is more than 73^{o}F.

Drainage and Permeability: Adamsville soils are somewhat poorly drained. Permeability is rapid. The water table is at 20 to 40 inches for 2 to 6 months during most years. It is at 10 to 20 inches for periods of up to two weeks in some years. It is within depths 60 inches for more than 9 months in most years.

Use and Vegetation: With adequate water control, many areas are used for truck crops, citrus and improved pasture. Natural vegetation is saw palmetto, cabbage palmettos, pine, laurel and water oaks and a ground cover of pineland three-awn and native weeds.

Distribution and Extent: Peninsular Florida. The series is of moderate extent.

Series Established: Hillsborough County, Florida; 1951.

Remarks: These soils were formerly classified as Regosols intergrading to Low-Humic Gley soils.

Myakka Series

The Myakka series consists of deep, poorly drained soils formed in sandy marine deposits. These soils have rapid permeability in the A horizons and moderate or moderately rapid permeability in the Bh horizons. Slopes range from 0 to 2 percent. Mean annual precipitation is about 50 inches and mean annual temperature is about 73^{o}F.

Taxonomic Class: Sandy, siliceous, hyperthermic Aeric Haplaquods.

Typical Pedon: Myakka sand - range.
(Colors are for moist soil unless otherwise stated.)

A1 - 0 to 6" - Black (10YR 2/1 crushed) sand; weak fine granular structure; very friable; matted with many fine and medium roots; strongly acid; clear smooth boundary. (4 to 8 inches thick)

A2 - 6 to 20" - White (10YR 8/2)sand; common fine faint vertical dark grayish brown, dark gray, and gray streaks along root channels; single grained; loose; common fine and medium roots; strongly acid; abrupt wavy boundary. (12 to 25 inches thick)

B21h - 20 to 24" - Black (N 2/) sand; weak coarse subangular blocky structure; weakly cemented; many fine and medium roots; sand grained coated with organic matter except for common fine pockets of uncoated sand grains; very strongly acid; clear wavy boundary. (2 to 4 inches thick)

B22h - 24 to 32" - Dark reddish brown (5YR 2/2) sand; common coarse faint vertical tongues of very dark brown (10YR 2/2) weak coarse subangular blocky structure; weakly cemented; many fine and medium roots; sand grains coated with organic matter; very strongly acid; clear smooth boundary. (0 to 10 inches thick)

B23h - 32 to 36" - Dark reddish brown (5YR 2/2) sand; weak fine granular structure; very friable; few fine roots; sand grains coated with organic matter; strongly acid; clear wavy boundary. (4 to 8 inches thick)

B3&Bh - 36 to 56" - Dark brown (7.5YR 4/4) sand; weak fine granular structure; very friable; few fine roots; common medium distinct dark reddish brown (5YR 2/2) bodies that are weakly cemented; strongly acid; clear wavy boundary. (3 to 22 inches thick)

C - 56 to 85"- Dark grayish brown (10YR 4/2) sand; single grained; loose; few fine roots; strongly acid.

Type location: Lake County, Florida; about 0.5 mile east of State Highway 448A and 100 feet south of Zellwood road in NW1/4SE1/4 sec. 24 T. 20 S., R. 26 E.

Range in Characteristics: Combined thickness of the A and Bh horizons is more than 40 inches. These soils range from extremely acid to slightly acid.

Crushed color of the A1 is black (10YR 2/1; N 2/), very dark gray (10YR 3/1; N 3/), dark gray (10YR 4/1; N 4/). Uncrushed colors have a salt-and-pepper appearance.

The A2 horizon is gray (10YR 5/1, 6/1; N 6/), light gray (10YR 7/1; N 7/), or white (10 YR 8/1, 8/2; N 8/ ; 2.5Y 8/2). In some pedons this horizons has gray, yellow, and brown mottles. A transition layer from the A2 to the Bh horizon, 1/2 to 2 inches thick, occurs in many pedons. The A horizons are sand or fine sand. Total thickness of the A horizons ranges from 20 to 30 inches.

The Bh horizon is black (5YR 2/1; N 2/ ; 10YR 2/1), dark reddish brown (5YR 2/2, 3/2, 3/3, 3/4), dark brown (7.5YR 3/2), very dark brown (10YR 2/2), or very dark gray (5YR 3/1). Colors range to dark brown (10YR 3/3) if sand grains are well coated with organic matter. The Bh horizon is sand, loamy fine sand, or fine sand. Where the color is black, thickness is less than 12 inches. Sand grains in this horizon are weakly cemented.

The B3&Bh horizon is dark brown (7.5YR 4/4, 3/2; 10YR 3/3, 4/3) or brown (10YR 5/3) with medium and coarse dark reddish brown (5YR 2/2, 3/2, 3/3) and black (10YR 2/1; 5YR 2/1) weakly cemented bodies. A B3 horizon, where present, is similar in color to the B3&Bh horizon but includes pale brown (10YR 6/3), dark yellowish brown (10YR 3/4, 4/4), brown (7.5YR 4/4, 5/4), or yellowish brown (10YR 5/4).

The B2h horizon has 0.60 to 4 percent organic carbon content and iron content is less than 0.5 percent. Medium to doarse vertical or horizontal tongues and/or pockets of gray, light brownish gray, or light gray sand range from none to common in the Bh horizon.

Some pedons have A'2 and B'h horizons below the Bh horizon. The A'2 when present, has hue of 10YR, value of 4 to 7 and chroma 2 to 4, with brown and gray mottles in some pedons. The B'2h, when present, has color similar to the Bh horizon but is generally friable and non-cemented.

The C horizon is brown (10YR 5/3; 7.5YR 4/4, 5/4), very pale brown (10YR 7/3, 7/4) gray (10YR 5/1), dark grayish brown (10YR 4/2) light brownish gray (10YR 6/2), or grayish brown (10YR 5/2), with or without mottles of brown, yellow, or gray.

Geographic Setting: Myakka soils occur on nearly level areas with gradients of 0 to 2 percent. The soil formed in marine deposits of sandy materials. Near the type location, rainfall averages about 50 inches annually with mean annual air temperature of more than 73°F.

Drainage and Permeability: Myakka soils are poorly drained. They have slow internal drainage and slow runoff. Permeability is rapid in the A horizon and moderate or moderately rapid in the Bh horizon. The water table is at depths of less than 10 inches for 1 to 4 months duration in most years and recedes to depths of more than 40 inches during very dry seasons. Depressions

are covered with standing water for periods of 6 to 9 months or more in most years.

Use and Vegetation: Most areas are used for forest and range. Large areas with adequate water management are used for citrus, improved pasture, and truck crops. Native vegetation consists of longleaf and slash pines with an undergrowth of saw palmetto, runner oak, gallberry, wax myrtle, huckleberry, pineland threeawn, and scattered fetterbushes.

Distribution and Extent: Peninsular Florida. The series is of large extent and is important in the area of occurrence.

Series Established: Lake County, Florida; 1970.

Remarks: Myakka soils were formerly classified in the Leon series as Ground-Water Podzols.

Sparr Series

The Sparr series consists of somewhat poorly drained, moderately permeable soils formed in thick beds of sandy and loamy marine sediments. The subsoil is saturated in the summer. Water runs off the surface slowly. Slope ranges from 0 to 8 percent.

Taxonomic Class: Loamy, siliceous, hyperthermic Grossarenic Paleudults.

Typical Pedon: Sparr fine sand - cultivated.
(Colors are moist soil unless otherwise stated.)

Ap1 - 0 to 5" - Dark gray (10YR 4/1) fine sand; moderate medium and coarse crumb structure; very friable; many fine and few roots; very strongly acid; clear wavy boundary. (4 to 8 inches thick)

Ap2 - 5 to 8" - Mixed dark gray (10YR 4/1), grayish brown (10YR 5/2), and pale brown (10YR 6/3) fine sand; weak medium crumb structure; very friable; many fine and few medium roots;

strongly acid; clear wavy boundary. (2 to 4 inches thick)

A2 - 8 to 39" - Very pale brown (10YR 7/4) fine sand; common fine distinct light gray mottles; few medium and coarse grayish brown (10YR 5/2) krotovina; single grained; loose; common fine roots; many uncoated sand grains; strongly acid; clear wavy boundary. (28 to 48 inches thick)

A3 - 39 to 48" - Yellowish brown (10YR 5/4) fine sand; few fine faint yellowish brown and common fine distinct light gray mottles; single grained; loose; few fine roots; strongly acid; clear wavy boundary. (0 to 20 inches thick)

B21t - 48 to 56" - Yellowish brown (10YR 5/4) fine sandy loam, ;few fine distinct gray and common medium prominent yellowish red (5YR 5/8) mottles; weak medium subangular blocky structure; friable; very few roots; few fine pores; clay bridging between sand grains; about 3 percent plinthite; very strongly acid; clear wavy boundary. (3 to 10 inches thick)

B22tg - 56 to 72" - Gray (N 5/) sandy clay; common fine and medium prominent yellowish red (5YR 5/6) mottles; moderate medium subangular blocky structure; friable; very few roots; few fine pores; clay films on faces of peds; about 2 percent plinthite; strongly acid; clear wavy boundary. (12 to 20 inches thick)

B3g - 72 to 100"- Gray (N 5/) sandy clay loam with lenses of sandy loam material; common medium distinct strong brown (7.5YR 5/6) and few fine distinct pale brown mottles; weak medium subangular blocky structure; friable; very strongly acid.

Type Location: Marion County, Florida; about 4.1 miles south of Ocala, 1/4 mile west of U.S. Highway 441. NW 1/4 SE 1/4 sec. 4, T. 16 S., R 22E.

Range in Characteristics: Solum thickness is 60 or more inches. Soil reaction ranges from very strongly acid to slightly acid in all horizons.

The A1 or Ap horizon has hue of 10YR, value 4 or 5, chroma 1 or 2.

The A2 horizon has hue of 10YR, value 5 or 6, chroma 1 to 4, or value 7 or 8, chroma 3 or 4.

The A3 horizon, where present, has hue of 10YR, value 5, chroma 4 to 8 or value 6, chroma 4 with grayish mottles that are indicative of wetness. The A horizon is sand or fine sand.

The B2t horizon has hue of 10YR, value 5, chroma 4 to 8, or value 6 or 7, chroma 3 or 4 with mottles in shades of brown, yellow, gray, and red. It is sandy loam, fine sandy loam, or sandy clay loam.

The B2tg horizon has hue of 10YR or N, value 5 to 7, chroma 2 or less with mottles in shades of gray, yellow, brown, and red. It is sandy loam, fine sandy loam, sandy clay loam, or light sandy clay. Content of plinthite ranges from 0 to 5 percent in the Bt horizons.

Some pedons have a B1 horizon. It has hue of 10YR, value 5, chroma 4 to 8, or value 6, chroma 3 or 4. It is loamy sand, loamy fine sand, sandy loam, or fine sandy loam 0 to 4 inches thick.

The B3g horizon has hue of 10YR or N, value 5 to 7, chroma 1 or less with common or many mottles in shades of gray, yellow, brown, red. It is a sandy loam, fine sandy loam, or sandy clay loam.

Geographic Setting: Sparr soils are on nearly level to sloping uplands in the Coastal Plain. Slopes are 0 to 8 percent. The soil formed in thick beds of sandy and loamy marine sediments. Near the type location, average annual rainfall is about 59 inches and mean annual air temperature is about 72°F.

Drainage and Permeability: Somewhat poorly drained; slow runoff; moderate permeability. The water table in these soils is at depths of 20 to 40 inches for periods of 1 to 4 months. The water table is usually perched on the surface of the loamy layers.

Use and Vegetation: Most areas of this soil are cleared and used for corn, citrus, peanuts, watermelons, truck crops, and improved pasture. Native vegetation consists of longleaf, slash, and loblolly pine, magnolia, dogwood, hickory, and live and water oaks.

Distribution and Extent: Peninsular Florida. The series is of moderate extent.

Series Established: Marion County, Florida; 1974.

Remarks: This soil was formerly classified in the Regosol great soil group.

Wauchula Series

The Wauchula series is a member of the sandy over loamy, siliceous, hyperthermic family of Ultic Haplaquods. These soils have a sandy dark colored A1 horizon and a sandy light colored A2 horizon that total less than 30 inches thick over a Bh horizon and an underlying Bt horizon with low base saturation.

Typifying Pedon: Wauchula fine sand - forested.
(Colors are for moist soil unless otherwise stated.)

A11 - 0 - 3" - Black (10YR 2/1 crushed) fine sand; weak fine crumb structure; friable; many fine medium and coarse roots; strongly acid; clear wavy boundary. (2 to 4 inches thick)

A12 - 3 - 7" - Very dark gray (10YR 3/1 crushed) fine sand; single grained; loose; many fine medium and coarse roots; strongly acid; clear wavy boundary. (2 to 4 inches thick)

A21 - 7 - 12" - Gray (10YR 5/1) fine sand; single grained; loose; common medium roots; streaks of dark and very dark gray along root channels; very strongly acid; clear smooth boundary. (3 to 5 inches thick)

A22 - 12 - 21" - Light gray (10YR 7/1) fine sand; single grained; loose; narrow vertical dark gray and very dark gray streaks in the matrix and along root channels; few to common fine and medium roots; very strongly acid; ½- to 2-inch transition layer of dark grayish brown; clear wavy boundary. (6 to 10 inches thick)

B21h - 21 - 25" - Black (5YR 2/1) fine sand; weak fine subangular blocky structure crushing to moderate fine crumb structure; friable; firm; weakly cemented; many sand grains are well coated with organic matter; few sand grains are clean; many fine and medium roots; very strongly acid; gradual wavy boundary. (3 to 6 inches thick)

B22h - 25 - 28" - Dark reddish brown (5YR 2/2) fine sand; weak fine crumb structure; friable; firm; weakly cemented; few fine and medium roots; many sand grains are well coated with organic matter; very strongly acid; clear wavy boundary. (3 to 6 inches thick)

B3 - 28 - 31" - Brown (10YR 4/3) fine sand; few medium faint very dark brown streaks and mottles; single grained; loose; some sand grains are thinly coated with organic matter; very strongly acid; gradual wavy boundary. (2 to 4 inches thick)

A'2 - 31 - 37" - Pale brown (10YR 6/3) fine sand; few fine faint streaks of very dark grayish brown; single grained; very strongly acid; gradual wavy boundary. (0 to 6 inches thick)

B'1t - 37 - 46" - Grayish brown (10YR 5/2) fine sandy loam; few medium prominent red (2.5Y 4/8) and distinct brownish yellow (10YR 6/8) mottles; weak fine granular structure; friable; sand grains are bridged and coated with clay; few fine light gray (10YR 7/1) sand lenses; very strongly acid; gradual wavy boundary. (2 to 12 inches thick)

B'2t - 46 - 65" - Gray (N 6/) sandy clay loam; few coarse distinct reddish yellow (7.5YR 6/6); strong brown (7.5YR 5/8) and dark brown (7.5YR 4/4) mottles; weak fine subangular blocky structure; friable; slightly sticky; sand grains are distinctly coated and bridged with clay; few patchy clay films on ped faces and in root channels; very strongly acid; gradual wavy boundary. (10 to 24 inches thick)

B'3 - 65 - 80" - Gray (N 6/) fine sandy loam; few fine distinct brownish yellow and strong brown mottles; massive; friable; slightly sticky; sand grains are coated and weakly bridged with clay; few fine sand lenses; very strongly acid.

Type Location: Hardee County, Florida; about 1,500 feet west of Peace River and 1,700 feet north of State Road 64 in NW1/4NE1/4, sec. 3, R. 25 E., T 34 S.

Range in Characteristics: Soil reaction is very strongly or strongly acid throughout. The A1 or Ap horizon is black (10YR 2/1), very dark gray (10YR 4/1), or dark grayish brown (10YR 4/2) sand or fine sand. This horizon is

a mixture of organic matter and clean sand grains when dry. The A2 horizon is gray (10YR 5/1, 6/1; N 5/ , N 6/), grayish brown (10YR 5/2), light brownish gray (10YR 6/2), light gray (10YR 7/1, 7/2; N 7/), or white (10YR 8/1, 8/2; N 8) sand or fine sand. Some pedons have mottles in shades of yellow, brown, or red. The Bh horizon is black (10YR 2/1; 5YR 2/1), very dark brown (10YR 2/2), dark brown (10YR 3/3; 7.5YR 3/2), or dark reddish brown (5YR 2/2, 3/2, 3/3, 3/4) sand or fine sand. Sand grains in this horizon are thinly or thickly coated with organic matter; consistence ranges from soft to firm and weakly cemented. The B3 horizon is brown (10YR 4/3, 5/3; 7.5YR 4/2, 4/4), pale brown (10YR 6/3), dark yellowish brown (10YR 3/4, 4/4). In many pedons few to common, fine to coarse weakly cemented Bh bodies are in this horizon. When present, the A'2 horizon is very pale brown (10YR 7/3, 7/4), pale brown (10YR 6/3), light brownish gray (10YR 6/2), gray (10YR 5/1, 6/1), or light gray (10YR 7/1, 7/2) sand or fine sand. The B't horizon is gray (10YR 5/1, 6/1; N 5/ , N 6/), grayish brown (10YR 5/2; 2.5Y 5/2), dark gray (10YR 4/1), dark grayish brown (10YR 4/2; 2.5Y 4/2) sandy loam through sandy clay loam. Mottles in shades of brown, yellow, or red are in this horizon. In some pedons, lenses of sandy material are in this horizon. Clay content in this horizon ranges from about 15 to 35 percent. The Bt horizon has base saturation of less than 35 percent and occurs in the soil at depths of 21 to 40 inches.

Setting: Wauchula soils are on nearly level areas of the lower Coastal Plain. They have formed in sandy over moderately fine-textured marine deposits. At the type location average annual precipitation is about 55 to 60 inches and mean annual temperature is about 74°F.

Drainage and Permeability: Poorly drained; slow runoff; moderately rapid or moderate permeability. Water table rises to depths of less than 10 inches

for 1 to 4 months during most years. It is at depths of about 10 to 40 inches for periods ranging to about 6 months, but during the driest season it recedes to depths of more than 40 inches.

Use and Vegetation: Large areas of this soil are used for improved pasture and range. With adequate water control, some areas of this soil are used for citrus and vegetable crops. Natural vegetation consists of longleaf and slash pines, saw palmetto, and an understory of gallberry, fetter, wax myrtle, and pineland threeawn.

Distribution and Extent: Peninsular Florida. The series is of moderate extent.

Series Established: Lake County, Florida; 1970.

Remarks: These soils were formerly included in the Leon series and classified in the Ground-Water Podzol great soil group.

APPENDIX C

PROCEDURE FOR THE TWO-STAGE *IN VITRO* ORGANIC MATTER DIGESTION OF FORAGES

1. Obtain four empty tubes for blanks (media only; no forage sample).

2. Turn on water bath and incubator (39°C).

3. Prepare appropriate quantity of buffer in 3½ gallon bottle (40 ml per tube plus about 200 ml extra), add 1 ml 4% $CaCl_2$ per liter and place bottle in 39°C water bath. When large volumes (e.g. 8 liters) are required, prepare saliva prior to the day of inoculation and allow it to warm up in water bath (39°C) overnight prior to inoculation.

4. Bubble CO_2 through the artificial saliva at a gentle rate. CO_2 may be started the day of inoculation.

5. Add 2 ml distilled water to all centrifuge tubes (including blanks) with automatic pipette, wet all forage particles by agitation using test tube mixer (do not do this until the day of inoculation).

6. Check pH of artificial saliva; it should be approximately 6.9 - 7.0; the CO_2 bubbling through the solution lowers the pH; when solution is saturated with CO_2 and the bicarbonate buffer system is established, the pH will be 6.9 - 7.0.

7. Prepare inoculum as described in 4 above and add one (1) part rumen fluid to four (4) parts artificial saliva.

8. Allow the media (rumen fluid plus saliva) to mix for 10 minutes through the action of the bubbling CO_2.

9. Add 50 ml of media to each centrifuge tube, including blanks, using the dispensing burette (add media to the tubes at random and disperse the blanks randomly among the set of tubes).

10. Immediately after adding media, place tubes in waterbath, flush the remaining air out of the tubes by passing CO_2 into the tube for 15 seconds (do not bubble CO_2 into the media in the tubes); quickly stopper the tubes with the bunsen valve. (Note: addition of media is achieved most rapidly when two tubes are flushed simultaneously using the two 2-hole stoppers and when two technitions work together, one adding media and the other flushing and stoppering tubes.)

11. Transfer tubes to incubator at 39°C (including blanks).

12. After one hour incubation, swirl contents in tubes, by hand, with a gentle rotating motion, to insure that all forage particles are wet with media; repeat twice the first day and three times the second day.

13. After 48 hours incubation, remove the stoppers and wash any forage particles adhering to the stoppers into the tube with a minimum of distilled water; check pH of a few tubes at random, should be less than 7.

14. Add 1 ml 20% HCl, swirl tubes; add another 1 ml 20%HCl, swirl; and finally add 4 ml 20% HCl and swirl (total HCl = 6 ml/tube); pH of media should be about 1 - 2 (to avoid excess foam, wait until each increment of acid is added to all tubes before swirling).

15. Add 2 ml 5% pepsin, swirl thoroughly, replace stoppers and return tubes to incubator at 39°C; repeat swirling twice the first day three times the second.

16. Prepare gooch crucibles by forming a glass wool mat from 3 - 4 pieces of glass wool (cut glass wool into squares, about ½", using paper cutter).

17. After 46 hours pepsin digestion, transfer the contents of the centrifuge tubes to the gooch crucibles using the crucible holder; use low vacuum, filtration should be rapid. Wash all residue from tube into crucible with

hot distilled water. Wash residue in gooch crucible three times with hot distilled water.

18. Place gooch crucibles in drying oven at 105°C and dry to constant weight (overnight), cool in desiccator and weigh.

19. Place crucibles in muffle furnace at 500°C for 3 hours, cool in dessiccator and weigh.

APPENDIX D

SOIL STUDY DATA

APPENDIX D

Table D.1. Average organic matter content and coefficients of variation (%) for soils at three depths, 0 - 10, 10 - 20, and 20 - 30 cm at the BRU.

Treatment Month rest	I $\bar{X}$	I CV	II $\bar{X}$	II CV	III $\bar{X}$	III CV	IV $\bar{X}$	IV CV	$\bar{X}$
				0 - 10 cm depth					
2	3.18	23.2	2.25	24.6	3.07	24.2	2.72	22.0	2.80a
4	5.66	48.5	3.43	28.2	3.22	37.6	4.32	60.7	4.16b
6	4.25	29.2	3.21	29.1	2.52	26.9	2.38	25.7	3.09a
12	4.21	58.7	2.35	33.6	2.64	37.8	2.62	63.2	2.96a
$\bar{X}$	4.33a		2.80ab		2.86b		3.01b		
	Trt F = 5.856				Blk F = 8.029				
				10 - 20 cm depth					
2	1.56	24.4	1.27	27.3	1.49	22.5	1.11	33.7	1.36a
4	2.80	43.3	1.52	33.6	1.81	27.4	1.66	59.6	1.95a
6	1.61	34.0	1.42	30.8	0.99	22.9	1.08	16.9	1.28a
12	2.12	43.6	0.96	34.0	1.23	18.6	0.82	44.0	1.28a
$\bar{X}$	2.02a		1.29b		1.38b		1.17b		
	Trt F = 5.637				Blk F = 7.838				
				20 - 30 cm depth					
2	1.19	26.4	0.98	21.1	1.04	18.6	0.92	24.4	1.03a
4	2.13	34.5	1.69	30.0	1.52	56.8	0.98	49.5	1.58b
6	1.91	31.4	1.20	28.8	0.71	26.8	0.85	17.7	1.17a
12	1.87	38.0	0.76	38.2	0.79	38.2	0.67	52.0	1.02a
$\bar{X}$	1.78a		1.16b		1.02b		0.86b		
	Trt F = 4.075				Blk F = 9.654				

Note: Numbers followed by same letter are not significant at $P < .05$ level.

Table D.2. Average pH and coefficients of variations (%) for soils at three depths, 0 - 10, 10 - 20, and 20 - 30 cm, at the BRU.

	Replication								
Treatment	I		II		III		IV		
month rest	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$
				0 - 10 cm depth					
2	4.38	5.3	4.56	6.4	4.57	6.1	4.5	7.2	4.45a
4	4.26	6.8	3.97	6.5	4.28	6.2	3.93	7.9	4.11a
6	4.09	7.1	4.11	8.1	4.17	8.3	4.55	7.1	4.23a
12	4.27	4.7	4.01	6.0	4.87	6.8	3.90	7.9	4.01a
$\bar{X}$	4.25a		4.16a		4.22a		4.17a		
	Trt F = 0.170				Blk F = 3.450				
				10 - 20 cm depth					
2	4.70	3.9	4.76	5.1	4.75	3.5	4.54	7.00	4.69a
4	4.48	11.4	4.29	12.2	4.59	9.7	4.18	13.3	4.39a
6	4.31	5.7	4.41	5.7	4.49	6.0	4.84	6.5	4.51a
12	4.55	4.3	4.35	6.7	4.87	6.1	4.18	5.9	4.49a
$\bar{X}$	4.51a		4.45a		4.68a		4.44a		
	Trt F = 1.378				Blk F = 1.044				
				20 - 30 cm depth					
2	4.75	5.6	4.85	4.0	4.82	3.6	4.58	5.0	4.75
4	4.63	10.7	4.58	9.8	4.72	8.6	4.37	13.2	4.58a
6	4.58	5.9	4.53	5.5	4.59	4.8	4.95	7.7	4.75a
12	4.68	3.6	4.50	4.9	4.89	5.0	4.27	6.2	4.59a
$\bar{X}$	4.66a		4.62a		4.84a		4.54a		
	Trt F = 1.243				Blk F = 2.098				

Note: Numbers followed by same letters are not significant at the $P < 0.05$ level.

Table D.3. Average phosphorus content (ppm) and coefficients of variation (%) for soils at three depths, 0 - 10, 10 - 20, and 20 - 30 cm, at the BRU.

Treatment month rest	I $\bar{X}$	I CV	II $\bar{X}$	II CV	III $\bar{X}$	III CV	IV $\bar{X}$	IV CV	$\bar{X}$
					Replication				
					0 - 10 cm depth				
2	4.15	66.9	5.24	107.2	4.57	104.5	1.07	47.1	3.76a
4	1.91	80.2	2.31	81.3	3.22	84.9	1.19	134.9	2.16a
6	2.11	81.2	1.73	95.4	5.89	73.5	7.03	147.5	4.19a
12	2.71	61.5	0.75	129.9	10.24	65.1	0.51	91.6	3.55a
$\bar{X}$	2.72a		2.51a		5.98a		2.45a		
	Trt F = 0.456				Blk F = 1.735				
					10 - 20 cm depth				
2	8.93	114.3	9.88	116.9	5.13	150.9	2.27	145.2	6.55a
4	1.59	72.6	5.65	186.0	7.63	154.5	0.75	91.3	3.91a
6	2.54	121.4	1.76	93.8	15.49	67.5	4.78	112.9	6.14a
12	5.10	137.2	2.52	176.5	17.91	88.9	0.46	101.9	6.50a
$\bar{X}$	4.54ab		4.95a		11.54a		2.07a		
	Trt F = 0.320				Blk F = 3.309				
					20 -30 cm depth				
2	11.65	183.1	10.14	195.4	3.11	132.4	3.04	130.6	6.99a
4	1.65	89.6	4.19	132.3	9.43	152.5	0.57	73.2	3.96a
6	3.43	134.5	1.40	52.2	11.21	80.7	2.02	79.8	4.52a
12	3.59	96.3	1.26	142.4	10.49	82.4	0.39	96.1	3.93a
$\bar{X}$	5.08a		4.25a		8.56a		1.50a		
	Trt F = 0.572				Blk F = 2.300				

Note; Numbers followed by same letters are not significant at the $P < 0.05$ level.

Table D.4. Average potassium content (ppm) and coefficients of variation (%) for soils at three depths, 0 - 10, 10 - 20, and 20 - 30 cm, at the BRU.

Treatment month rest	I $\bar{X}$	I CV	II $\bar{X}$	II CV	III $\bar{X}$	III CV	IV $\bar{X}$	IV CV	$\bar{X}$
				0 - 10 cm depth					
2	11.4	41.0	9.6	33.4	11.4	53.0	10.13	18.6	10.63a
4	20.4	12.6	13.73	30.0	9.87	33.9	11.80	46.9	13.95a
6	15.67	28.7	15.8	57.4	9.40	43.8	14.73	103.4	13.90a
12	12.73	20.9	9.13	32.8	9.47	28.7	8.07	36.1	9.85a
$\bar{X}$	15.05a		12.07a		10.04a		11.18a		
		Trt F = 3.331				Blk F = 3.315			
				10 - 20 cm depth					
2	4.8	31.7	4.53	37.2	5.27	30.8	4.13	31.5	4.68a
4	9.13	25.8	5.47	30.0	4.53	41.6	4.53	27.5	5.92a
6	6.80	20.2	6.00	44.1	4.40	26.9	5.73	39.3	5.73a
12	5.93	24.2	4.47	29.1	4.07	45.9	3.73	32.8	4.55a
$\bar{X}$	6.67a		5.12ab		4.57b		4.53b		
		Trt F = 2.010				Blk F = 4.065			
				20 - 30 cm depth					
2	2.93	35.3	2.67	36.6	2.73	32.4	2.97	47.2	2.80a
4	5.87	48.1	4.80	46.7	2.80	59.1	2.60	37.9	4.02a
6	5.40	26.9	3.47	39.1	3.73	23.7	4.07	35.3	4.17a
12	4.67	41.9	3.53	36.9	2.87	41.4	2.87	39.2	3.49a
$\bar{X}$	4.72a		3.62ab		3.03b		3.10b		
		Trt F = 2.946				Blk F = 4.662			

Note: Numbers followed by the same letter are not significant at the $P < 0.05$ level.

Table D. 5. Average calcium content (ppm) and coefficients of variation (%) for soils at three depths, 0 - 10, 10 - 20, and 20 - 30 cm, at the BRU.

Treatment month rest	I $\bar{X}$	I CV	II $\bar{X}$	II CV	III $\bar{X}$	III CV	IV $\bar{X}$	IV CV	$\bar{X}$
					Replication				
					0 - 10 cm depth				
2	184.7	36.8	155.9	29.2	205.1	32.9	158.7	30.8	176.1a
4	241.9	52.0	219.3	63.7	126.0	39.5	150.1	41.0	184.3a
6	260.7	42.6	196.1	42.6	135.6	19.8	137.2	33.7	182.4a
12	188.9	26.4	152.9	27.8	115.6	50.1	97.7	28.3	138.8a
$\bar{X}$	219.0a		181.1a		145.6b		135.9b		
	Trt F = 1.808				Blk F = 5.659				
					10 - 20 cm depth				
2	74.3	23.3	84.5	28.7	99.6	13.0	72.5	25.0	84.0a
4	127.7	47.2	76.0	39.5	62.4	28.6	78.9	26.2	86.3a
6	97.5	35.7	93.6	43.1	86.9	22.2	92.9	28.5	92.7a
12	100.1	22.3	81.2	24.1	88.1	46.7	57.5	18.8	81.7a
$\bar{X}$	101.2a		83.8a		84.3a		75.5a		
	Trt F = 0.328				Blk F = 1.691				
					20 - 30 cm depth				
2	63.8	20.9	67.7	32.8	81.5	14.8	63.1	20.2	69.0a
4	92.5	33.4	63.6	33.3	47.7	22.6	63.5	22.1	66.8a
6	64.9	28.8	77.6	25.1	82.0	21.5	75.2	17.0	74.9a
12	82.3	23.2	71.6	23.5	79.7	40.4	63.5	25.1	74.3a
$\bar{X}$	75.9a		70.1a		72.7a		66.3a		
	Trt F = 0.392				Blk F = 0.408				

Note: Numbers followed by the same letter are not significant at the $P < 0.05$ level.

Table D.6. Average magnesium content (ppm) and coefficients of variation (%) for soils at three depths, 0 - 10, 10 - 20, and 20 - 30 cm at the BRU.

Treatment month rest	I $\bar{X}$	I CV	II $\bar{X}$	II CV	III $\bar{X}$	III CV	IV $\bar{X}$	IV CV	$\bar{X}$
				0 - 10 cm depth					
2	25.4	33.8	18.5	44.0	29.6	48.8	20.2	39.8	23.4a
4	36.4	58.8	32.4	51.5	16.8	55.5	26.1	48.3	28.0a
6	40.7	31.7	19.5	52.9	14.2	32.5	16.2	74.1	25.1a
12	30.6	57.0	20.4	30.7	13.2	62.7	16.9	46.2	20.3a
$\bar{X}$	33.3a		25.2ab		18.4b		14.9b		
	Trt F = 0.979				Blk F = 4.278				
				10 - 20 cm depth					
2	5.7	28.2	6.1	48.9	6.9	30.8	5.6	62.1	6.1a
4	12.7	73.3	6.4	42.3	4.5	46.8	9.5	58.7	8.3a
6	11.3	54.2	7.9	82.8	5.0	30.7	6.2	59.8	7.6a
12	8.9	66.3	7.6	37.4	6.9	62.0	6.0	40.1	7.4a
$\bar{X}$	9.6a		7.0a		5.8a		6.8a		
	Trt F = 0.881				Blk F = 2.757				
				20 - 30 cm depth					
2	3.1	33.7	3.4	45.0	4.2	35.1	3.4	54.9	3.5a
4	5.8	60.6	3.4	39.1	2.4	43.6	5.2	35.0	4.2a
6	4.2	51.1	4.2	58.4	3.6	37.9	4.5	41.6	4.1a
12	4.2	78.5	5.5	57.8	5.3	64.4	5.0	47.7	5.0a
$\bar{X}$	4.3a		4.1a		3.9a		4.5a		
	Trt F = 1.540				Blk F = 0.313				

Note: Numbers followed by same letter are not significant at the $P < 0.05$ level.

APPENDIX E

HERBAGE DATA

APPENDIX E

Table E.1. Digestibilities of range species collected at study site - seasonal collections.

Species	Season	X (ppm)	s (ppm)	CV (%)		# Samples
Andropogon virginicus	Summer 1976	15.43	2.24	14.5		5
	Fall 1976	24.51	3.46	14.1		3
	Winter 1976	21.14	2.90	13.7		4
	Spring 1977	26.52	4.14	15.6		3
	Summer 1977	22.01	2.84	12.9		4
	Fall 1977	27.00	3.50	13.0		2
	Year average	22.77	4.29	18.8	Total	21
Anthaenantia villosa	Fall 1977	52.38	-	-		1
Aristida stricta	Summer 1976	17.57	3.30	18.8		24
	Fall 1976	15.17	2.67	17.6		36
	Winter 1976	13.25	1.93	14.5		21
	Spring 1977	15.54	2.70	17.4		21
	Summer 1977	14.16	2.86	20.2		104
	Fall 1977	16.26	1.89	11.6		26
	Year average	15.33	1.53	10.0	Total	232
Axonopos affinis	Fall 1977	39.55	-	-		1
Callicarpa americana (berries)	Summer 1976	35.39	-	-		1
	Fall 1976	36.24	2.41	13.3		2
	Summer 1977	40.24	10.06	25.0		18
	Fall 1977	32.84	-	-		1
	Year average	36.18	3.07	8.5	Total	22
Cassia nictitans	Summer 1976	19.30	4.03	20.9		8
	Fall 1976	22.63	3.61	16.0		21
	Spring 1977	28.17	4.31	15.3		3
	Summer 1977	22.05	3.14	14.2		21
	Fall 1977	27.14	1.45	5.4		4
	Year average	23.86	3.71	15.5	Total	57

Table E. 1. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Centella asiatica	Winter 1976	13.90	-	-		1
	Fall 1977	39.71	3.30	8.3		4
Centrosema spp.	Summer 1976	38.94	8.77	22.5		10
	Fall 1976	36.89	5.02	13.6		3
	Spring 1977	15.72	1.27	7.8		2
	Summer 1977	40.20	4.86	12.1		4
	Fall 1977	36.19	5.65	15.6		3
	Year average	33.59	10.12	30.1	Total	22
Ctenium aromaticum	Summer 1976	25.06	2.38	9.5		22
	Fall 1976	23.51	3.69	15.7		25
	Winter 1976	21.63	2.95	13.6		11
	Spring 1977	24.46	2.53	10.3		5
	Summer 1977	22.88	2.40	10.5		9
	Fall 1977	20.99	0.85	4.0		2
	Year average	23.09	1.58	6.9	Total	74
Desmodium spp.	Summer 1976	14.02	-	-		1
	Summer 1977	20.11	3.17	15.8		19
Elephantopus tomentosus	Fall 1977	42.72	-	-		1
Eragrostis spectabilis	Summer 1976	38.72	4.61	11.9		4
	Fall 1976	30.85	4.69	15.2		6
	Winter 1976	24.68	3.36	13.6		5
	Spring 1977	31.51	6.33	20.1		5
	Summer 1977	30.12	4.85	16.1		3
	Fall 1977	34.88	4.78	13.7		5
	Year average	31.79	4.73	14.9	Total	28
Galactia spp.	Summer 1976	34.05	6.11	17.9		19
	Fall 1976	27.13	4.92	18.1		14
	Spring 1977	41.22	7.20	17.5		10
	Summer 1977	32.27	5.56	17.2		26
	Fall 1977	31.42	5.13	16.3		7
	Year average	33.33	5.15	15.5	Total	76

Table E. 1. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Heterotheca graminifolia	Summer 1976	36.03	5.75	15.9		28
	Fall 1976	34.20	7.21	21.1		28
	Winter 1976	40.68	6.53	16.0		21
	Spring 1977	41.18	7.88	19.3		18
	Summer 1977	34.80	5.31	15.2		30
	Fall 1977	31.72	5.75	18.1		25
	Year average	36.44	3.76	10.3	Total	150
Ilex glabra	Summer 1977	34.61	0.88	2.5		2
	Fall 1977	39.58	1.07	2.7		2
Lespedeza spp.	Spring 1977	45.21	-	-		1
Lyonia lucida	Summer 1977	28.07	-	-		1
	Fall 1977	28.43	0.40	1.4		2
Panicum anceps	Summer 1976	51.11	6.16	12.1		9
	Fall 1976	38.12	-	-		1
	Winter 1976	39.06	7.74	19.8		3
	Spring 1977	54.66	8.04	14.7		6
	Summer 1977	49.49	2.31	4.7		2
	Fall 1977	47.74	3.46	7.2		4
	Year average	46.70	6.69	14.3	Total	25
Paspalum notatum	Summer 1976	48.63	5.40	11.1		3
	Fall 1976	44.22	5.39	12.2		2
	Winter 1976	36.88	4.54	12.3		2
	Spring 1977	57.50	5.64	9.8		2
	Summer 1977	50.68	5.22	10.3		3
	Fall 1977	42.43	-	-		1
	Year average	46.72	7.17	15.3	Total	13
Pteridium aquilinum	Summer 1977	7.36	2.97	40.4		2
	Fall 1977	7.83	2.02	25.8		2

Table E. 1. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Quercus incana	Summer 1976	22.93	3.37	14.5		29
	Fall 1976	22.33	3.10	13.9		25
	Winter 1976	22.77	1.82	8.0		6
	Spring 1977	21.85	3.05	14.0		12
	Summer 1977	21.21	4.35	20.5		21
	Fall 1977	21.93	2.64	12.0		10
	Year average	22.17	0.64	2.9	Total	103
Quercus pumila	Summer 1976	20.93	3.58	17.1		4
	Fall 1976	19.07	3.18	16.1		7
	Winter 1976	17.56	2.69	15.3		8
	Spring 1977	18.35	3.06	16.7		3
	Summer 1977	19.35	2.78	13.8		39
	Fall 1977	21.37	3.37	15.7		27
	Year average	19.44	1.47	7.6	Total	88
Rhus copallina	Fall 1977	26.04	-	-		1
Rhynchosia spp.	Fall 1976	32.55	-	-		1
Rubus spp.	Fall 1977	28.35	-	-		1
Schizachyrium stolonifer	Summer 1976	31.55	6.15	19.5		35
	Fall 1976	30.14	3.97	13.2		27
	Winter 1976	27.25	3.47	12.7		3
	Spring 1977	34.19	5.65	16.5		10
	Summer 1977	28.05	3.02	10.8		4
	Fall 1977	35.22	4.63	13.1		25
	Year average	31.07	3.22	10.4	Total	104
Scleria mulhenbergia	Summer 1976	31.32	15.92	50.8		3
	Summer 1977	38.62	-	-		1

Table E. 1. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Serenoa repens	Summer 1976	18.29	2.83	15.4		8
	Fall 1976	16.63	2.96	17.8		5
	Winter 1976	23.58	1.87	7.9		7
	Spring 1977	21.98	2.78	12.6		10
	Summer 1977	18.54	1.99	10.7		25
	Fall 1977	16.76	2.74	16.4		12
	Year average	19.30	2.85	14.8	Total	67
Smilax auriculata	Summer 1976	30.23	5.86	19.4		9
	Fall 1976	34.41	6.30	18.3		6
	Winter 1976	27.89	2.58	9.2		4
	Spring 1977	33.21	2.21	6.7		4
	Summer 1977	37.21	5.84	15.7		17
	Fall 1977	27.92	1.03	3.7		4
	Year average	31.81	3.76	11.8	Total	44
Sorgastrum nutans	Summer 1976	34.63	1.72	5.0		8
	Fall 1976	19.54	3.42	17.5		3
	Winter 1976	17.67	2.51	14.2		3
	Spring 1977	26.85	-	-		1
	Summer 1977	29.09	5.86	20.2		2
	Fall 1977	31.74	3.90	12.3		4
	Year average	26.59	6.73	25.3	Total	21
Sporobolus curtissii	Summer 1976	26.43	3.39	12.8		16
	Fall 1976	22.84	2.36	10.3		8
	Winter 1976	21.45	3.11	14.5		4
	Spring 1977	18.82	1.48	7.9		4
	Summer 1977	20.73	2.72	13.1		5
	Fall 1977	17.91	4.66	26.0		3
	Year average	21.36	3.05	14.3	Total	40
Sporobolus junceus	Fall 1977	20.77	-	-		1
Stillingia sylvatica	Fall 1977	32.17	-	-		1

Table E. 1. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Stipa avenacea	Summer 1977	30.88	3.99	12.9		2
Tephrosia spp.	Summer 1976	32.97	3.25	10.1		8
	Fall 1976	35.75	1.94	5.4		5
	Spring 1977	40.90	5.36	13.1		6
	Summer 1977	31.96	3.43	10.7		17
	Fall 1977	31.12	3.58	11.5		5
	Year average	34.36	4.07	11.8	Total	41
Tillandsia usenoides	Fall 1977	29.50	2.84	9.6		2
Trilisa paniculata	Summer 1976	51.74	4.02	7.8		3
	Summer 1977	49.79	4.59	9.2		17
Triplasia americana	Summer 1977	34.40	2.16	6.3		2
	Fall 1977	26.24	3.34	12.7		3
Vaccinium myrsinites	Summer 1976	33.89	6.77	20.0		5
	Fall 1976	31.72	5.62	17.7		9
	Winter 1976	26.62	2.96	11.2		6
	Spring 1977	38.97	6.27	16.1		7
	Summer 1977	31.85	3.21	10.1		20
	Fall 1977	31.33	4.69	15.0		7
	Year average	32.40	4.02	12.4	Total	54
Woodwardia virginica	Spring 1977	20.55	-	-		1
Xyris spp.	Fall 1977	17.07	-	-		1

Table E.2. Phosphorus content of range species collected at the BRU - seasonal collections.

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Andropogon virginicus	Summer 1976	1262	-	-		1
	Fall 1976	946	173.8	18.4		3
	Winter 1976	851	87.7	10.3		3
	Spring 1977	1120	135.5	12.1		3
	Summer 1977	1087	157.6	14.5		4
	Fall 1977	839	41.0	4.8		2
	Average	1018	167.2	16.4	Total	16
Anthaenantia villosa	Fall 1977	1951	-	-		1
Aristida stricta	Summer 1976	672	177.1	26.4		26
	Fall 1976	733	167.7	22.9		37
	Winter 1976	598	186.1	31.1		23
	Spring 1977	582	237.2	40.8		20
	Summer 1977	739	286.0	38.7		77
	Fall 1977	629	153.6	24.4		24
	Average	659	67.2	10.2	Total	207
Axonopus affinis	Fall 1977	1109	-	-		1
Callicarpa americana (berries)	Summer 1976	1942	-	-		1
	Fall 1976	1766	294.9	16.7		2
	Summer 1977	2720	479.8	18.3		17
	Fall 1977	2530	488.3	19.3		3
	Average	2240	437.5	20.4	Total	23
Cassia nictitans	Summer 1976	1392	635.1	45.6		4
	Fall 1976	1158	238.6	20.6		12
	Spring 1977	2891	563.7	19.5		6
	Summer 1977	2115	450.5	21.3		19
	Fall 1977	1344	114.2	8.5		3
	Average	1780	720.1	40.5	Total	44

Table E.2. - continued

Species	Season		$\overline{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Centella asiatica	Fall	1976	1230	148.8	12.1		3
	Winter	1976	1211	-	-		1
	Fall	1977	1596	36.1	2.3		2
Centrosema spp.	Summer	1976	1402	352.4	25.1		3
	Fall	1976	1395	-	-		1
	Spring	1977	1512	189.0	12.5		2
	Summer	1977	1355	249.3	18.4		3
	Fall	1977	2275	434.5	19.1		2
	Average		1588	388.5	24.5	Total	12
Ctenium aromaticum	Summer	1976	1463	377.6	25.8		8
	Fall	1976	1336	395.7	29.6		9
	Winter	1976	715	143.7	20.1		2
	Spring	1977	1276	-	-		1
	Summer	1977	1466	833.0	56.8		5
	Fall	1977	1399	246.2	17.6		5
	Average		1276	284.4	22.3	Total	30
Desmodium spp.	Summer	1976	1332	107.6	8.1		3
	Summer	1977	2010	564.0	28.1		17
Elephantopus tomentosus	Fall	1977	1900	-	-		1
Eragrostis spectabilis	Summer	1976	1544	333.5	21.6		2
	Fall	1976	1075	209.6	19.5		3
	Winter	1977	809	-	-		1
	Spring	1977	1064	210.7	19.8		4
	Summer	1977	1396	244.3	17.5		3
	Fall	1977	1530	325.9	21.3		2
	Average		1236	298.2	24.1	Total	15
Galactia spp.	Summer	1976	1227	272.2	22.2		24
	Fall	1976	986	226.1	22.9		17
	Spring	1977	2722	434.8	16.0		4
	Summer	1977	1694	319.3	18.9		91
	Fall	1977	1358	235.1	17.3		4
	Average		1597	678.7	42.5	Total	140

Table E.2. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Heterotheca graminifolia	Summer 1976	1122	317.0	28.3		38
	Fall 1976	1167	254.9	21.8		45
	Winter 1976	981	239.2	24.4		26
	Spring 1977	1326	254.9	19.2		22
	Summer 1977	1053	237.3	22.5		15
	Fall 1977	1274	335.2	26.3		27
	Average	1154	130.6	11.3	Total	173
Ilex glabra	Summer 1977	583	14.8	2.5		2
	Fall 1977	475	48.8	10.3		2
Lespedeza spp.	Spring 1977	1167	-	-		1
Lyonia lucida	Summer 1977	430	-	-		1
	Fall 1977	301	21.2	7.0		2
Panicum aciculare	Summer 1977	1036	276.2	26.7		6
	Fall 1977	1074	43.8	4.1		2
Panicum anceps	Summer 1976	1470	298.6	20.3		6
	Fall 1976	1348	830.1	61.6		3
	Winter 1976	1385	724.2	52.3		3
	Spring 1977	1055	-	-		1
	Summer 1977	1713	89.1	5.2		2
	Fall 1977	1499	401.6	26.8		4
	Average	1412	216.2	15.3	Total	19
Paspalum notatum	Fall 1977	2566	-	-		1
Pteridium aquillinum	Summer 1977	519	-	-		1
	Fall 1977	851	484.8	57.0		3
Quercus incana	Summer 1976	1018	329.3	32.3		31
	Fall 1976	951	235.0	24.7		24
	Winter 1976	972	107.0	11.0		6
	Spring 1977	1172	249.9	21.3		11
	Summer 1977	840	177.8	21.2		10
	Fall 1977	885	140.4	15.9		13
	Average	973	116.2	11.9	Total	95

Table E.2. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Quercus pumila	Summer 1976	1607	342.3	21.3		4
	Fall 1976	1501	297.2	19.8		5
	Winter 1976	1456	326.1	22.4		4
	Spring 1977	1736	283.0	16.3		6
	Summer 1977	1249	296.9	23.8		44
	Fall 1977	1007	262.1	26.0		20
	Average	1426	261.6	18.3	Total	83
Rhus copallina	Fall 1977	1507	-	-		1
Rhynchosia spp.	Summer 1976	1571	-	-		1
Rubus spp.	Summer 1977	1032	-	-		1
	Fall 1977	1190	134.5	11.3		2
Schizachyrium stolonifer	Summer 1976	1218	340.7	28.0		17
	Fall 1976	1051	385.1	36.6		10
	Winter 1976	981	286.1	29.2		3
	Spring 1977	1291	380.9	29.5		4
	Summer 1977	988	284.7	18.8		6
	Fall 1977	1082	236.5	21.9		10
	Average	1102	126.3	11.5	Total	50
Scleria mulhenbergia	Summer 1976	1108	551.5	49.8		2
	Winter 1976	840	182.3	21.7		3
Serenoa repens	Summer 1976	835	274.3	32.9		10
	Fall 1976	956	117.9	12.3		10
	Winter 1976	693	155.3	22.4		8
	Spring 1977	730	185.8	25.5		10
	Summer 1977	1126	324.9	28.9		42
	Fall 1977	679	233.4	34.4		9
	Average	837	176.0	21.0	Total	89

Table E.2. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Smilax auriculata	Summer 1976	691	168.6	24.4	6
	Fall 1976	875	112.3	12.8	4
	Winter 1976	760	71.4	9.4	4
	Spring 1977	807	119.7	14.8	5
	Summer 1977	1279	416.7	32.6	86
	Fall 1977	711	73.2	10.3	4
	Average	854	218.7	25.6	Total 109
Sorghastrum nutans	Summer 1976	1112	343.7	30.9	6
	Fall 1976	943	229.1	24.3	3
	Winter 1976	896	101.2	11.3	2
	Spring 1977	1327	-	-	1
	Summer 1977	1454	306.8	21.1	2
	Fall 1977	1594	315.6	19.8	3
	Average	1221	282.6	23.1	Total 17
Sporobolus curtissii	Summer 1976	956	457.2	47.8	9
	Fall 1976	668	146.8	22.0	9
	Winter 1976	533	7.1	1.3	2
	Spring 1977	426	100.6	23.6	4
	Summer 1977	1031	227.9	22.1	5
	Fall 1977	1390	615.7	44.3	3
	Average	834	359.8	43.1	Total 32
Sporobulus junceus	Fall 1976	1576	-	-	1
Stillingia sylvatica	Fall 1977	896	-	-	1
Tephrosia spp.	Summer 1976	1480	416.6	28.2	5
	Fall 1976	1454	413.7	28.4	2
	Spring 1976	2348	366.3	15.6	4
	Summer 1977	1718	268.0	15.6	17
	Fall 1977	1344	178.8	13.3	3
	Average	1669	403.4	24.2	Total 31
Tillandsia useniodes	Fall 1977	440	154.9	3.5	2

Table E.2. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Trilisa paniculata	Summer 1976	974	235.7	24.2	3
	Fall 1977	674	55.2	8.2	2
Triplasia americana	Fall 1977	726	-	-	1
Vaccinium myrsinites	Summer 1976	570	163.5	28.7	4
	Fall 1976	756	101.8	13.5	6
	Winter 1976	593	100.9	17.0	5
	Spring 1977	805	80.7	10.0	4
	Summer 1977	698	126.1	18.1	23
	Fall 1977	690	263.2	38.2	7
	Average	685	90.0	13.3	Total 49
Woodwardia virginica	Spring 1977	2436	-	-	1
Xyris spp.	Fall 1977	373	-	-	1
				Grand total	1307

Table E.3. Calcium content of range species collected at study site.

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Andropogon virginicus	Summer 1976	4358	-	-	1
	Fall 1976	1356	584.8	43.2	2
	Winter 1976	1048	189.7	18.1	3
	Spring 1977	1413	299.6	21.2	3
	Summer 1977	2741	540.0	19.7	4
	Fall 1977	3245	207.2	6.4	2
	Average	2360	1307.4	55.4	Total 15
Anthaenantia villosa	Fall 1977	4122	-	-	1
Aristida stricta	Summer 1976	1361	281.3	20.7	25
	Fall 1976	1612	335.0	20.8	37
	Winter 1976	1360	306.8	22.6	23
	Spring 1977	1599	545.6	34.1	20
	Summer 1977	1622	430.6	26.5	72
	Fall 1977	1838	472.8	25.7	20
	Average	1565	181.5	11.6	Total 197
Axonopus affinis	Fall 1977	3899	-	-	1
Callicarpa americana (berries)	Summer 1976	7064	-	-	1
	Fall 1976	10203	1561.1	15.3	2
	Summer 1977	2720	505.9	18.6	17
	Fall 1977	3929	636.5	16.2	3
	Average	5979	3358.7	56.2	Total 23
Cassia nictitans	Summer 1976	5801	1953.2	33.7	4
	Fall 1976	6541	1164.3	17.8	12
	Spring 1977	7285	1333.2	18.3	6
	Summer 1977	7962	808.6	10.2	19
	Fall 1977	9381	2108.4	22.5	3
	Average	7394	1373.7	18.6	Total 44

Table E.3. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Centella asiatica	Fall 1976	13117	3226.8	24.6	3
	Winter 1976	2683	-	-	1
	Fall 1977	1327	41.0	0.3	2
Centrosema spp.	Summer 1976	10097	4753.5	47.1	3
	Fall 1976	10012	-	-	1
	Spring 1977	6601	1399.4	21.2	2
	Summer 1977	5534	1278.4	23.1	3
	Fall 1977	13112	2373.3	18.1	2
	Average	9071	3036.4	33.5	Total 11
Ctenium aromaticum	Summer 1976	2769	453.2	16.4	8
	Fall 1976	3030	1254.1	41.4	9
	Winter 1976	1603	2.8	0.2	2
	Spring 1977	3615	-	-	1
	Summer 1977	1836	190.2	10.4	3
	Fall 1977	2284	452.2	19.8	5
	Average	2523	759.7	30.1	Total 28
Desmodium spp.	Summer 1976	6744	2526.3	37.5	3
	Summer 1977	10032	1578.4	15.7	17
Elephantopus tomentosus	Fall 1977	9602	-	-	1
Eragrostis spectabilis	Summer 1976	2353	428.2	18.2	2
	Fall 1976	2840	488.5	17.2	3
	Winter 1976	2184	-	-	1
	Spring 1977	2946	492.0	16.7	4
	Summer 1977	1801	362.0	20.1	3
	Fall 1977	2814	371.4	13.2	2
	Average	2490	452.2	18.2	Total 15
Galactia spp.	Summer 1976	8650	3088.6	35.7	24
	Fall 1976	11373	2974.0	26.1	15
	Spring 1976	10000	4224.8	42.2	4
	Summer 1977	11675	1534.3	13.1	83
	Fall 1977	12092	4437.4	36.7	5
	Average	10758	1415.6	13.2	Total 131

Table E.3. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Heterotheca graminifolia	Summer 1976	7817	2510.5	32.1	38
	Fall 1976	9017	2484.7	27.6	49
	Winter 1976	8301	2138.2	25.8	26
	Spring 1977	9806	2239.5	22.8	23
	Summer 1977	7684	1145.2	14.9	15
	Fall 1977	9597	1840.6	19.2	27
	Average	8704	905.5	10.4	Total 178
Ilex glabra	Summer 1977	7042	87.7	1.2	2
	Fall 1977	7782	710.6	9.1	2
Lespedeza spp.	Spring 1977	8329	807.9	9.7	2
Lyonia lucida	Summer 1977	9090	-	-	1
	Fall 1977	14788	14.8	0.1	2
Panicum aciculare	Summer 1977	2216	825.3	37.2	6
	Fall 1977	1901	92.6	4.9	2
Panicum anceps	Summer 1976	4922	1672.0	34.0	6
	Fall 1976	6038	697.1	11.5	3
	Winter 1976	6062	1987.4	32.8	3
	Spring 1977	3794	-	-	1
	Summer 1977	6466	1167.4	18.1	2
	Fall 1977	3070	987.6	32.2	4
	Average	5059	1379.7	27.3	Total 19
Paspalum notatum	Fall 1977	3621	-	-	1
Pteridium aquilinum	Summer 1977	6336	-	-	1
	Fall 1977	4772	576.4	11.9	3
Quercus incana	Summer 1976	8208	2345.6	28.6	31
	Fall 1976	9548	2834.5	29.7	24
	Winter 1976	10919	2144.1	19.6	6
	Spring 1977	6860	2593.0	37.8	11
	Summer 1977	6183	1785.7	28.9	9
	Fall 1977	8093	2819.9	34.8	12
	Average	8302	1733.4	20.9	Total 93

Table E.3. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Quercus incana	Summer 1976	8123	1372.8	16.9		4
	Fall 1976	9702	1775.5	18.3		5
	Winter 1976	10920	1878.2	17.2		4
	Spring 1977	9738	2346.9	24.1		6
	Summer 1977	9151	3171.0	34.6		42
	Fall 1977	6873	2688.3	39.1		22
	Average	9085	1414.0	15.6	Total	83
Rhus copallina	Fall 1977	9832	-	-		1
Rhynchosia spp.	Summer 1976	4733	-	-		1
Rubus spp.	Summer 1977	15133	-	-		1
	Fall 1977	9142	1033.0	11.3		2
Schizachyrium stolonifer	Summer 1976	3725	2364.3	63.5		17
	Fall 1976	3759	2341.0	62.3		10
	Winter 1976	2799	360.4	12.9		3
	Spring 1977	3775	2258.3	59.8		4
	Summer 1977	4083	1880.4	46.1		6
	Fall 1977	3666	2313.0	63.1		13
	Average	3635	434.4	12.0	Total	53
Scleria mulhenbergia	Summer 1976	11516	3202.5	27.8		2
	Winter 1976	4141	977.3	23.6		4
Serenoa repens	Summer 1976	1650	484.6	29.4		10
	Fall 1976	1888	658.5	34.9		10
	Winter 1976	1609	452.0	28.1		8
	Spring 1977	2715	282.0	10.4		10
	Summer 1977	2107	1162.5	55.2		43
	Fall 1977	2409	1199.7	49.8		8
	Average	2063	436.8	21.2	Total	89
Smilax auriculata	Summer 1976	7415	1913.1	25.8		7
	Fall 1976	8131	2736.7	33.7		4
	Winter 1976	8733	5424.2	62.1		4
	Spring 1977	4592	2861.7	62.3		3

Table E. 3. - continued

Species	Seasons	$\bar{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Smilax auriculata	Summer 1977	8392	1946.3	23.2	82
	Fall 1977	6984	1416.0	20.3	4
	Average	7375	1506.6	20.4	Total 104
Sorghastrum nutans	Summer 1976	3608	1864.8	51.7	6
	Fall 1976	3509	1094.8	31.2	3
	Winter 1976	2710	804.9	29.7	2
	Spring 1977	5823	-	-	1
	Summer 1977	5553	2591.5	46.7	2
	Fall 1977	8674	2350.7	27.1	2
	Average	4980	2185.6	43.9	Total 16
Sporobolus curtissii	Summer 1976	2894	1908.4	65.9	8
	Fall 1976	1595	700.9	43.9	9
	Winter 1976	1379	133.8	9.7	3
	Spring 1977	1435	186.6	13.0	4
	Summer 1977	4144	795.6	19.2	5
	Fall 1977	2356	143.0	6.1	3
	Average	2301	1081.6	47.0	Total 31
Sporobolus junceus	Fall 1977	1801	48.5	2.7	3
Stillingia sylvatica	Fall 1977	14614	-	-	1
Tephrosia spp.	Summer 1976	7089	3114.6	43.9	5
	Fall 1976	11916	1575.8	13.2	2
	Spring 1977	10313	2299.8	22.3	4
	Summer 1977	11235	1890.5	16.8	17
	Fall 1977	18885	5155.6	27.3	3
	Average	11888	4327.1	36.4	Total 31
Tillandsia usenoides	Fall 1977	11551	1009.7	8.7	2
Trilisa paniculata	Summer 1976	10231	4252.5	41.6	3
	Fall 1977	13473	152.7	1.1	2

Table E. 3. - continued

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Triplasia americana	Fall 1977	3547	-	-	1
Vaccinium myrsinites	Summer 1976	5616	1598.7	28.5	4
	Fall 1976	4497	1380.7	30.7	6
	Winter 1976	6948	1590.1	22.9	5
	Spring 1977	4487	1298.0	28.9	4
	Summer 1977	9626	881.9	9.2	23
	Fall 1977	9098	627.3	6.9	7
	Average	6712	2249.4	33.5	Total 49
Woodwardia virginica	Spring 1977	16305	-	-	1
Xyris spp.	Summer 1977	3973	-	-	1
	Fall 1977	3776	-	-	1
				Grand Total	1288

Table E. 4. Potassium content of range species collected at the BRU - seasonal collections.

Species	Season	$\bar{X}$ (ppm)	s (ppm)	CV (%)	# Samples
Andropogon virginicus	Summer 1976	1492	-	-	1
	Fall 1976	3065	1505.0	49.1	3
	Winter 1976	1957	366.0	18.7	3
	Spring 1977	1586	493.2	31.1	3
	Summer 1977	1343	382.8	28.5	4
	Fall 1977	2169	468.5	21.6	2
	Average	1935	632.6	32.7	Total 16
Anthaenantia villosa	Fall 1977	1977	-	-	1
Aristida stricta	Summer 1976	3465	1578.8	45.6	26
	Fall 1976	2605	971.2	37.3	41
	Winter 1976	2120	703.9	33.2	22
	Spring 1977	2303	1113.9	48.4	20
	Summer 1977	2386	938.2	39.3	75
	Fall 1977	2188	1051.2	48.0	24
	Average	2511	497.0	19.8	Total 208
Axonopus affinis	Fall 1977	3513	-	-	1
Callicarpa americana (berries)	Summer 1976	2255	-	-	1
	Fall 1976	9447	2947.5	31.2	2
	Summer 1977	16448	2247.2	13.7	17
	Fall 1977	10300	5283.9	51.3	3
	Average	9613	5812.5	60.5	Total 23
Cassia nictitans	Summer 1976	5827	2533.8	43.5	4
	Fall 1976	3909	1300.7	33.3	12
	Spring 1977	8921	12783.4	31.2	6
	Summer 1977	8703	2129.3	24.5	20
	Fall 1977	6391	2151.2	33.7	3
	Average	6750	2096.4	31.1	Total 43

Table E. 4. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)	# Samples	
Centella asiatica	Fall 1976	7433	1984.6	26.7		3
	Winter 1976	5680	-	-		1
	Fall 1977	8116	163.3	2.0		2
Centrosema spp.	Summer 1976	6161	220.7	3.6		3
	Fall 1976	6685	-	-		1
	Spring 1977	6680	1810.3	27.1		2
	Summer 1977	4955	1405.8	28.2		3
	Fall 1977	8400	1369.2	16.3		2
	Average	6576	1239.9	18.9	Total	11
Ctenium aromaticum	Summer 1976	2884	959.1	33.3		7
	Fall 1976	2127	617.6	29.0		9
	Winter 1976	2773	585.1	21.1		2
	Spring 1977	2902	-	-		1
	Summer 1977	2540	1238.0	48.7		5
	Fall 1977	1730	543.2	31.4		5
	Average	2493	472.6	19.0	Total	29
Desmodium spp.	Summer 1976	9552	2224.5	23.3		3
	Summer 1977	7564	3203.4	42.4		17
Elephantopus tomentosus	Fall 1977	11368	-	-		1
Eragrostis spectabilis	Summer 1976	1948	352.6	18.1		2
	Fall 1976	6139	1172.5	19.1		3
	Winter 1976	3437	-	-		1
	Spring 1977	2785	632.2	22.7		4
	Summer 1977	3496	821.6	23.5		3
	Fall 1977	3810	582.9	15.3		2
	Average	3603	1408.6	39.1	Total	15
Galactia spp.	Summer 1976	7608	6365.8	83.7		24
	Fall 1976	4868	4785.3	98.3		17
	Spring 1977	7997	3127.9	39.1		4
	Summer 1977	9181	18652.1	203.2		89
	Fall 1977	5454	1701.0	31.2		5
	Average	7022	1806.5	25.7	Total	139

Table E. 4. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)	# Samples	
Heterotheca graminifolia	Summer 1976	8549	4086.2	47.8		38
	Fall 1976	8602	2893.0	33.6		51
	Winter 1976	9622	3522.5	36.6		24
	Spring 1977	10539	3974.7	37.7		23
	Summer 1977	6366	2213.0	34.8		15
	Fall 1977	11073	3995.0	36.1		27
	Average	9125	1688.7	18.5	Total	178
Ilex glabra	Summer 1977	1560	138.6	8.9		2
	Fall 1977	3154	677.4	21.5		2
Lespedeza spp.	Spring 1977	2650	736.7	27.8		2
Lyonia lucida	Summer 1977	2964	-	-		1
	Fall 1977	1969	11.3	0.6		2
Panicum aciculare	Summer 1977	3921	1781.3	45.4		5
	Fall 1977	3644	2145.4	58.9		2
Panicum anceps	Summer 1976	4960	2209.2	44.5		6
	Fall 1976	9977	3460.9	34.7		3
	Winter 1976	4258	1467.0	34.5		3
	Spring 1977	12114	-	-		1
	Summer 1977	7125	3791.5	53.2		2
	Fall 1977	9415	3350.3	35.6		4
	Average	7975	3060.7	38.4	Total	19
Paspalum notatum	Fall 1977	8071	-	-		1
Pteridium aquilinum	Summer 1977	1682	-	-		1
	Fall 1977	3007	1766.0	58.7		3
Quercus incana	Summer 1976	4382	1699.2	38.8		28
	Fall 1976	3779	1341.8	35.5		24
	Winter 1976	2633	425.4	16.2		6
	Spring 1977	4778	1921.1	40.2		10
	Summer 1977	4591	2448.2	53.3		11
	Fall 1977	3993	2052.2	51.4		13

Table E. 4. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)	# Samples	
Quercus incana	Average	4026	776.4	19.3	Total	92
Quercus pumila	Summer 1976	3888	828.1	21.3		4
	Fall 1976	3140	571.5	18.2		5
	Winter 1976	2478	473.3	19.9		4
	Spring 1977	4497	957.9	21.3		6
	Summer 1977	4463	1357.7	30.4		43
	Fall 1977	4556	2246.4	49.3		20
	Average	3837	857.8	22.4	Total	82
Rhus copallina	Fall 1977	8334	-	-		1
Rhynchosia spp.	Summer 1976	5325	-	-		1
Rubus spp.	Summer 1977	2990	-	-		1
	Fall 1977	7606	2380.7	31.3		2
Schizachyrium stolonifer	Summer 1976	4586	2037.7	44.4		17
	Fall 1976	5879	4666.0	79.4		11
	Winter 1976	4204	2622.8	62.4		3
	Spring 1977	3406	860.8	25.3		4
	Summer 1977	3424	1764.9	51.5		6
	Fall 1977	4660	1394.0	29.9		13
	Average	4360	922.9	21.2	Total	54
Scleria mulhenbergia	Summer 1976	2680	6.4	0.2		2
	Winter 1976	8620	3068.7	35.6		4
Serenoa repens	Summer 1976	6677	3513.4	52.6		10
	Fall 1976	4116	2126.9	51.7		10
	Winter 1976	5372	3132.6	58.3		8
	Spring 1977	2471	839.6	34.0		10
	Summer 1977	10079	5317.2	52.8		43
	Fall 1977	5082	4055.0	79.8		9
	Average	5633	2589.5	46.0	Total	90

Table E. 4. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)	# Samples	
Smilax auriculata	Summer 1976	6007	2871.7	47.8		7
	Fall 1976	2808	1297.3	46.2		4
	Winter 1976	3674	1406.2	38.3		4
	Spring 1977	4753	4487.5	94.4		5
	Summer 1977	8046	16838.1	209.3		82
	Fall 1977	5771	3115.1	54.0		4
	Average	5177	1861.4	36.0	Total	106
Sorghastrum nutans	Summer 1976	5485	3414.3	62.2		6
	Fall 1976	6530	2696.9	41.3		3
	Winter 1976	4856	1850.1	38.1		2
	Spring 1977	2504	-	-		1
	Summer 1977	4370	843.4	19.3		2
	Fall 1977	4762	1504.8	31.6		2
	Average	4751	1334.8	28.1	Total	16
Sporobolus curtissii	Summer 1976	2716	897.1	33.0		8
	Fall 1976	2219	400.4	18.0		10
	Winter 1976	1369	207.0	15.1		3
	Spring 1977	4208	5652.4	134.3		4
	Summer 1977	2198	738.5	33.6		5
	Fall 1977	1882	215.1	11.4		3
	Average	2432	976.5	40.2	Total	33
Sporobolus junceus	Fall 1977	2030	1398.8	68.9		3
Stillingia sylvatica	Fall 1977	1812	-	-		1
Tephrosia spp.	Summer 1976	7592	3667.4	48.3		5
	Fall 1976	3289	316.8	9.6		2
	Spring 1977	5521	1706.0	30.9		4
	Summer 1977	5511	1111.9	20.2		17
	Fall 1977	5513	1576.7	28.6		3
	Average	5485	1521.9	27.7	Total	31
Tillandsia usenoides	Fall 1977	4256	422.1	9.9		2

Table E. 4. - continued

Species	Season	$\overline{X}$ (ppm)	s (ppm)	CV (%)		# Samples
Trilisa paniculata	Summer 1976	8270	2207.9	26.7		3
	Fall 1977	6343	200.1	3.2		2
Triplasia americana	Fall 1977	4044	-	-		1
Vaccinium myrsinites	Summer 1976	2527	699.6	27.7		4
	Fall 1976	2705	1048.7	38.8		6
	Winter 1976	2426	1004.6	41.4		5
	Spring 1977	2280	183.0	8.0		4
	Summer 1977	2637	625.7	23.7		22
	Fall 1977	2637	1114.5	42.3		7
	Average	2535	159.2	6.3	Total	48
Woodwardia virginica	Spring 1977	1678	-	-		1
Xyris spp.	Fall 1977	2522	-	-		1
					Grand Total	1306

Table E.5. Average foliar chemical composition (ppm) composited for eleven species for each pasture.

Replication	Treatment (months rest) 2	4	6	12
		Phosphorus		
I	1573	1448	1628	1363
CV(%)	44.4	43.0	43.5	47.5
II	1822	1668	1409	1351
CV(%)	48.3	46.5	49.9	42.3
III	1605	1539	1730	1616
CV(%)	50.2	43.7	42.8	44.1
IV	1340	1265	1456	1329
CV(%)	49.1	55.6	43.0	52.4
			Avg. CV	46.6%
		Calcium		
I	7510	7570	7270	6540
CV(%)	60.7	48.7	47.5	56.6
II	7650	7600	7490	7580
CV(%)	50.0	52.4	46.7	55.5
III	7300	7840	7770	7540
CV(%)	48.1	40.8	48.4	48.1
IV	7280	6790	6920	7530
CV(%)	56.9	53.1	65.9	57.6
			Avg. CV	52.3%
		Potassium		
I	6650	8780	7640	6340
CV(%)	55.9	53.6	53.0	58.0
II	7810	8900	7640	6750
CV(%)	60.3	59.5	56.1	60.0
III	7630	6950	7270	7810
CV(%)	62.4	56.4	63.9	54.2
IV	6610	5830	7710	6320
CV(%)	63.8	75.1	77.9	66.6
			Avg. CV	61.0%

Table E.6. Average P foliar content in pasture at beginning of experiment - 1976.

	Months rest 2	4	6	12
	Replication I			
$\overline{X}$	1067.0	1098.0	956.0	1110.0
s	412.0	400.0	289.0	404.0
CV	38.6	36.5	30.3	36.4
# Samples	31	13	15	48
	Replication II			
$\overline{X}$	1038.0	1017.0	972.0	885.0
s	320.0	247.0	301.0	254.0
CV	30.8	24.3	31.0	28.7
# Samples	31	13	16	37
	Replication III			
$\overline{X}$	1071.0	1361.0	1238.0	1450.0
s	450.0	304.0	419.0	351.0
CV	42.0	22.4	33.9	24.2
# Samples	28	8	11	23
	Replication IV			
$\overline{X}$	976.0	692.0	828.0	819.0
s	259.0	213.0	269.0	214.0
CV	26.5	30.8	32.5	26.1
# Samples	35	14	14	20

Total samples 357

ANOVA Analysis

All replications		Replication I and II	
Trt F = 0.200		Trt F = 0.741	
Blk F = 9.075		Blk F = 2.323	
Trt df = 3	ns @ $P < 0.1$	Trt df = 3	ns @ $P < 0.1$
Blk df = 3	$P < 0.005$	Blk df = 1	ns @ $P < 0.1$

Table E.7. Average P foliar content at pasture at end of experiment - 1977.

	Months rest			
	2	4	6	12
		Replication I		
$\overline{X}$	1334.0	1196.0	1212.0	1107.0
s	588.0	587.0	662.0	515.0
CV	44.1	49.1	54.6	46.5
# Samples	28	32	23	33
		Replication II		
$\overline{X}$	1282.0	1072.0	1300.0	1122.0
s	697.0	620.0	591.0	478.0
CV	54.3	57.8	45.5	42.6
# Samples	43	37	16	34
		Replication III		
$\overline{X}$	1326.0	1391.0	1438.0	1425.0
s	569.0	654.0	666.0	609.0
CV	42.9	47.0	46.3	42.8
# Samples	40	29	23	30
		Replication IV		
$\overline{X}$	1080.0	1016.0	1174.0	899.0
s	458.0	531.0	501.0	542.0
CV	42.4	52.2	42.7	60.2
# Samples	40	29	27	53
			Total samples 517	

ANOVA Analysis

All replications		Replication I and II	
Trt F = 2.944		Trt F = 4.277	
Blk F = 13.201		Blk F = 0.160	
Trt df = 3	$P < 0.100$	Trt df = 3	$P < 0.100$
Blk df = 3	$P < 0.005$	Blk df = 1	ns @ $P < 0.1$

Table E.8. Average chemical content of *Pinus palustris*, August 1977.

Pasture (Replication - Length of rest)	Nutrient (ppm)											
	P		Ca		K		Mg		Al		Fe	
	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$	CV	$\bar{X}$	CV
I - 2	430	9	950	28	1900	34	520	22	230	14	50	45
I - 4	410	14	1040	17	2060	33	480	16	220	26	78	77
I - 6	370	10	1320	10	1720	18	550	18	230	14	60	30
I - 12	400	14	1160	29	1690	24	520	17	220	22	43	50
II - 2	520	13	1230	15	1620	24	590	12	230	11	40	8
II - 4	420	16	1130	17	1830	18	450	10	200	19	21	23
II - 6	420	8	1120	18	1860	19	570	20	180	33	35	38
II - 12	420	10	1010	14	2250	16	370	10	240	37	28	19
III - 2	490	13	1440	7	1790	23	600	7	290	16	36	30
III - 4	460	35	1640	16	1480	43	660	17	320	22	45	23
III - 6	400	17	1380	17	1780	39	440	35	250	26	33	14
III - 12	480	11	1210	23	1860	21	540	15	300	20	33	34
IV - 2	390	4	1360	34	1800	33	440	32	260	5	31	18
IV - 4	460	18	1380	24	1830	34	660	19	220	37	30	14
Iv - 6	480	19	1380	26	1900	25	560	22	270	20	35	17
IV - 12	380	16	1160	39	1680	18	480	6	170	13	34	18

Note: Five samples per pasture.

Table E. 9. Average chemical content of Pinus palustris, March 1977 and March 1978 collections.

1978

Pasture (replication-length of rest)	P	CV	Ca	CV	K	CV
	Chemical content (ppm) and CV (%)					
1 - 2	840	10	2130	19	2910	7
1 - 4	790	14	2670	14	2200	31
1-- 6	750	11	2580	16	2490	10
1 - 12	690	9	2710	9	2790	21
4 - 4	730	9	2160	23	2570	20
4 - 12	800	11	2470	14	2360	18

1977

	P	CV
1 - 2	860	7
1 - 12	710	6

Table E.10. Functional groupings of biomass data for summer 1976 and summer 1977.

	Grasses		
Month rest	1976 Kg/ha	1977 Kg/ha	% Change
	Replication I		
2	300.0	480.8	60.3
4	617.2	580.3	-6.0
6	730.3	730.2	0.0
12	316.9	513.3	67.3
	Replication II		
2	578.2	1007.4	74.2
4	371.1	369.1	-0.5
6	403.2	210.5	-47.8
12	453.8	222.0	-51.1
	Replication III		
2	431.0	466.8	8.3
4	236.1	269.3	14.1
6	247.4	210.5	-14.9
12	129.5	180.3	39.2
	Replication IV		
2	203.0	212.2	4.5
4	429.6	191.4	-55.4
6	641.8	682.1	6.3
12	433.9	542.2	25.0

Table E.10. - continued

Month rest	1976 Kg/ha	1977 Kg/ha	% Change
	Forbs		
	Replication I		
2	172.9	108.7	-37.1
4	590.0	395.0	-33.2
6	534.4	384.1	-28.1
12	194.4	314.8	61.9
	Replication II		
2	330.8	170.2	-48.5
4	291.5	428.8	47.1
6	254.3	169.5	-33.3
12	371.2	189.7	-48.9
	Replication III		
2	330.2	273.4	-17.2
4	345.8	345.8	0.0
6	234.4	118.9	-49.3
12	295.0	330.3	12.0
	Replication IV		
2	275.1	128.8	-53.2
4	249.1	76.6	-69.2
6	237.8	157.2	-33.9
12	205.9	172.9	-16.0

Table E.10. - continued

	Shrubs		
Month rest	1976 Kg/ha	1977 Kg/ha	% Change
	Replication I		
2	320.5	159.2	-50.3
4	841.4	199.6	-76.3
6	712.9	1574.7	120.9
12	802.6	179.6	-77.6
	Replication II		
2	54.0	736.8	1264.4
4	1045.7	684.8	-34.5
6	1334.1	992.4	-25.6
12	1959.0	1462.5	-25.3
	Replication III		
2	417.8	529.0	26.6
4	158.6	293.9	85.3
6	726.5	108.0	-85.1
12	180.3	284.6	57.8
	Replication IV		
2	663.0	375.6	-43.3
4	1589.1	3231.1	103.3
6	541.6	2210.4	308.1
12	2522.1	2765.6	9.7

Table E.10. - continued

Month rest	Trees (under 1.5 m) 1976 Kg/ha	1977 Kg/ha	% Change
	Replication I		
2	583.7	338.3	-42.0
4	31.4	20.5	-34.7
6	81.3	329.4	305.2
12	295.3	153.4	-48.1
	Replication II		
2	446.3	231.7	-48.1
4	-	-	-
6	121.0	-	-
12	22.9	10.1	-55.9
	Replication III		
2	155.5	283.6	82.4
4	-	124.4	-
6	151.7	555.0	265.9
12	398.9	-	-
	Replication IV		
2	159.2	802.4	404.0
4	241.3	177.7	-26.4
6	570.7	723.1	26.7
12	324.9	269.1	-17.2

Table E.10. - continued

Month rest	Total live biomass 1976 Kg/ha	1977 Kg/ha	% Change
	Replication I		
2	1607.5	1225.1	-23.8
4	2131.1	1285.7	-39.7
6	2484.8	3367.0	35.5
12	1778.0	1251.2	-29.6
	Replication II		
2	1463.3	2166.6	48.1
4	1928.4	1658.4	-14.0
6	2412.0	1667.7	-30.9
12	2880.8	1884.3	-34.6
	Replication III		
2	1367.5	1175.6	-14.0
4	806.8	1075.8	33.3
6	1829.7	1343.7	-26.6
12	1011.1	854.4	-15.5
	Replication IV		
2	1488.9	1655.7	11.2
4	1767.4	3780.7	113.9
6	2183.3	3775.5	72.9
12	3529.8	3751.1	6.3

Table E.10. - continued

Month rest	Litter 1976 Kg/ha	1977 Kg/ha	% Change
	Replication I		
2	1951.3	4088.5	109.5
4	4588.8	3877.3	-15.5
6	1627.3	5471.9	236.3
12	1452.4	6927.1	376.9
	Replication II		
2	1931.6	4290.8	122.1
4	1828.3	4733.0	158.9
6	1419.6	3912.2	175.6
12	1405.3	3790.2	169.7
	Replication III		
2	793.7	3867.8	387.3
4	2567.8	4272.4	66.4
6	1161.2	3755.0	234.4
12	1299.7	5103.3	292.7
	Replication IV		
2	1205.6	4316.1	258.0
4	2239.1	4805.5	114.6
6	1356.7	3603.9	165.6
12	2095.6	3724.9	77.7

Table E. 11. Diversity indices of pastures, summer 1976, based on four 100 foot line transects per pasture.

Treatment month rest	Replication I	II	III	IV	$\bar{X}$
			H'		
2	1.233	1.250	1.326	1.303	1.278a
4	1.387	1.201	1.392	1.376	1.323a
6	1.239	1.192	1.402	1.313	1.287a
12	1.428	1.235	1.395	1.327	1.346a
$\bar{X}$	1.322a	1.220b	1.379a	1.330a	
	Trt F = 1.807		Blk F = 6.543*		
			species number		
2	44	42	48	47	42.3a
4	50	43	45	46	46.0a
6	43	41	45	42	42.8a
12	51	40	50	47	47.0a
$\bar{X}$	47.0a	41.5b	47.0a	45.5a	
	Trt F = 2.347		Blk F = 4.812*		
			J'		
2	0.750	0.770	0.789	0.779	0.772a
4	0.849	0.735	0.842	0.827	0.813a
6	0.759	0.739	0.848	0.809	0.789a
12	0.837	0.771	0.821	0.793	0.806a
$\bar{X}$	0.799a	0.754a	0.825a	0.802a	
	Trt F = 1.437		Blk F = 3.787		

* Significant at the $P < 0.05$ level.

Note; Numbers followed by the same letter are not significant at $P < 0.05$ level.

Table E. 12. Diversity indices of all pastures, summer 1977, based on four 100 foot line transects per pasture.

Treatment month rest	Replication I	II	III	IV	$\bar{X}$
			H'		
2	1.069	0.696	1.255	1.215	1.059a
4	1.327	1.057	1.384	1.234	1.251a
6	1.142	1.050	1.449	1.154	1.199a
12	1.305	1.009	1.349	1.130	1.198a
$\bar{X}$	1.211a	0.953b	1.359a	1.184a	
	Trt F = 2.961		Blk F = 12.330*		
			species number		
2	41	44	53	47	46.3a
4	48	41	49	45	45.8a
6	49	47	51	48	48.8a
12	59	42	48	46	48.8a
$\bar{X}$	49.3a	43.5a	50.3a	46.5a	
	Trt F = 0.528		Blk F = 1.893		
			J'		
2	0.663	0.424	0.728	0.727	0.636a
4	0.790	0.656	0.819	0.746	0.753a
6	0.676	0.628	0.849	0.687	0.710a
12	0.761	0.622	0.800	0.680	0.716a
$\bar{X}$	0.723a	0.583b	0.799a	0.710a	
	Trt F = 3.043		Blk F = 10.178*		

* Significant at the $P < 0.01$ level.

Note: Numbers followed by same letter are not significant at the $P < 0.05$ level.

Table E. 13. Frequency of leaf hits on line transects for the average of all treatments for September 1976 and 1977.

	Months Rest							
	2		4		6		12	
Trees	1976	1977	1976	1977	1976	1977	1976	1977
Acer rubrum	-	-	-	-	-	-	-	-
Diospyros virginiana	.54	.31	.15	.08	.36	.12	.24	.04
Pinus elliottii	-	-	-	-	-	-	-	-
Pinus palustris	.16	.34	.10	.06	.72	.82	.39	.56
Quercus geminata	-	.29	-	-	-	-	.06	-
Quercus incana	3.47	7.09	1.55	2.35	2.02	2.65	5.34	7.78
Quercus nigra	.04	.20	.97	1.52	.25	.42	.11	.38
Quercus myrtifolia	.10	-	-	-	-	.08	.03	.12
Misc. trees	-	-	.01	-	-	.08	-	.03
Total trees	4.17	8.24	2.79	4.05	3.35	4.16	6.17	8.91
Shrubs								
Asmina longifolia	.25	-	.15	-	.05	.09	.14	.01
Callicicarpa americana	.13	.04	.05	.08	.18	.11	-	-
Chrysobalanus oblongifolius	2.57	.91	1.31	.52	1.41	.57	.87	.53
Gaylussacia dumosa	2.17	.02	2.69	.21	.56	.19	2.40	.73
Ilex coriacea	-	.02	-	.11	-	-	.11	.19
Ilex glabra	.12	.34	1.66	2.27	.10	.03	.71	.51
Kalmia hirsuta	-	.02	-	-	-	-	.14	.15
Lyonia lucida	-	-	-	.02	-	.08	.50	.73
Myrica cerifera	.12	.29	.41	.56	.31	.54	.68	.84
Quercus pumila	9.59	9.09	5.11	6.11	9.61	11.03	8.70	8.24
Rhus spp.	.02	.09	-	.02	.20	.21	.12	.10
Rubus spp.	.61	.65	2.01	2.68	.57	.47	.36	-
Serenoa repens	2.26	2.40	4.65	6.41	6.61	8.69	7.58	10.61
Sorbus arbutifolia	-	-	-	-	-	-	-	-
Stillingia sylvatica	.32	.31	.61	.35	.52	.33	.29	.44

Note: All species are italicized.

Table E. 13. - continued

Shrubs (continued)	Months Rest 2 1976	2 1977	4 1976	4 1977	6 1976	6 1977	12 1976	12 1977
Vaccinium arboreaum	-	1.91	.18	1.86	-	.25	-	.44
Vaccinium myrsinites	1.08	1.52	1.03	1.41	.82	1.07	1.62	1.45
Misc. shrubs	.03	-	-	.05	.01	-	.08	-
Total shrubs	19.27	17.60	19.86	22.54	20.96	23.57	24.22	25.51
Vines								
Gelsemium sempervirens	.23	.05	.26	.48	.03	.03	.02	-
Smilax auriculata	2.36	1.58	.14	.19	.69	.71	.12	.15
Vitus rotundifolia	-	-	-	-	-	-	-	-
Misc. vines	-	-	-	-	-	-	.02	-
Total vines	2.60	1.63	.39	.67	.72	.74	.15	.15
Grasslikes								
Hypoxis spp.	-	-	-	-	-	-	-	-
Scleria mulhenbergia	.86	.51	1.03	.59	.64	.45	.54	.40
Misc. grasslikes	.64	.24	1.13	.79	.86	.28	1.71	.35
Total grasslikes	1.50	.74	2.17	1.38	1.50	.73	2.25	.75
Ferns								
Pteridium aquilinum	7.69	3.14	9.53	4.58	6.14	3.66	2.79	1.42
Misc. ferns	-	-	.34	-	-	-	-	-
Total ferns	7.69	3.14	9.87	4.58	6.14	3.66	2.79	1.42

Table E. 13. - continued

Grasses	Months Rest 2		4		6		12	
	1976	1977	1976	1977	1976	1977	1976	1977
Amphicarpum muhlenbergianum	-	-	-	-	.04	-	-	-
Andropogon capillipes	.10	.02	.51	.17	.20	T	.27	.04
Andropogon virginicus	.19	.15	2.85	1.22	.17	.40	.93	1.20
Andropogon spp.	1.34	.85	.17	.32	.40	.45	.50	.88
Anthaentia villosa	.23	.09	T	.05	.07	.06	.06	.13
Aristida stricta	19.78	31.16	9.58	17.75	15.37	24.61	12.06	20.76
Aristida spp.	.20	.33	.57	.97	.10	.50	.35	1.28
Axonopus affinis	-	.42	.42	1.21	-	.23	.08	.45
Ctenium aromaticum	1.49	4.19	1.71	2.70	1.44	1.68	2.78	1.63
Digitaria villosa	-	.49	-	-	.07	.16	-	.01
Erogrostis spectabilis	-	.74	-	.71	-	1.64	.08	1.88
Eremochloa ophioroides	-	.13	-	-	.23	.28	.50	.54
Panicum aciculare	1.42	1.09	1.95	2.33	1.94	.84	2.91	1.98
Panicum anceps	.01	.44	1.49	1.32	.90	1.38	.57	.63
Panicum hemitomon	-	-	.19	.05	-	-	.06	-
Panicum spp.	2.86	2.85	2.78	5.92	2.33	2.56	3.15	2.76
Paspalum notatum	.79	1.05	.87	1.51	.27	.74	.35	.32
Paspalum setaceum	-	.13	-	2.09	-	.96	-	.86
Paspalum spp.	.80	1.03	2.71	1.09	1.78	.51	2.36	.82
Schyizachyrium stolonifer	3.90	4.59	1.45	2.19	4.10	4.38	2.85	3.87
Setaria geniculata	-	-	-	.03	-	.03	-	.01
Sorghastrum nutans	.36	.25	.31	-	.55	.40	.42	.64
Sporobolus curtissii	.53	.62	1.47	1.63	1.81	1.96	1.95	1.33
Sporobolus junceus	.22	.02	.08	.03	1.61	1.60	.41	.67
Triplasis americana	-	-	-	-	-	.12	-	.32
Misc. grasses	.22	-	.41	.22	.47	.39	-	.09
Total grasses	34.45	52.40	29.51	42.32	33.85	45.88	32.61	43.01

Table E. 13. - continued

	Months Rest							
	2		4		6		12	
Legumes	1976	1977	1976	1977	1976	1977	1976	1977
Cassia nictitans	1.62	.40	1.67	1.24	1.21	1.37	1.47	.41
Centrosema spp.	1.37	.54	.17	.30	.10	.23	.33	.18
Crotalaria spp.	.12	.13	.04	.03	.18	.11	.08	.18
Desmodium spp.	.36	.29	1.31	.79	.61	.22	1.08	.53
Galactia spp.	7.67	.49	6.10	.27	7.33	.54	6.03	.31
Lespedeza spp.	.13	-	.10	.02	,01	.02	.08	-
Rhynchosia spp.	.04	-	.04	-	.17	.22	-	-
Tephrosia spp.	.19	.02	1.11	.13	1.22	.20	1.41	.18
Misc. legumes	.29	-	.08	-	.03	.03	.27	.04
Total legumes	11.07	1.92	10.82	2.78	10.87	2.93	10.74	1.85
Forbs								
Ambrosia artemisifolia	.18	.09	.08	-	-	.03	.20	.01
Centella asiatica	-	-	3.02	4.58	-	-	-	.07
Diodia teres	.02	.04	.05	.10	-	-	-	.01
Euphorbia spp.	.99	.42	.71	.30	.55	.22	.77	.23
Heterothecia graminifolia	5.43	4.63	6.69	6.71	8.17	8.02	7.13	10.00
Hypericum spp.	.06	.20	.38	.29	.01	.19	.20	.19
Rhexia mariana	-	.05	3.21	.79	.08	.11	.05	.09
Trilisa paniculata	-	-	-	-	-	.06	-	.01
Xyris ambigua	.61	.24	1.55	.19	1.67	.22	1.77	.40
Misc. asteraceae	5.78	6.28	4.88	5.39	6.74	5.60	3.74	3.87
Misc. forbs	4.65	.60	2.87	1.27	2.50	.81	2.70	.98
Total forbs	17.57	12.54	23.37	19.62	19.72	15.25	16.60	15.88
Litter	1.24	1.60	1.13	1.98	2.46	3.03	3.57	2.52
Bare ground	.44	-	.17	-	.44	.05	.90	-
Total number recorded hits	6854	5511	7849	6304	7683	6445	6664	6828

Note: Orginal data collected by W. H. Moore, Adjunct Prof., Sch. For. Res. and Conser., Univ. Fla.

APPENDIX F

HERBIVORE DATA

Table F. 1. Cattle weights (lbs) as entered and left study site, showing weight changes

Date In and Out	Cow Number								
	6[2]	122	134	135	248[3]	295	362	371	Steer
In 7/12/76	720	755	840	840	805	815	615	650	1460
7/17/76	705	765	875	860	830	870	655	650	1485
7/22/76	770	750	890	805	825	865	600	625	1475
Out 7/30/76	730	735	875	845	815	825	645	635	1480
Change	10	-20	35	5	10	10	30	-15	20
% change[1]	1.4	-2.6	4.2	0.6	1.2	1.2	4.9	-2.3	1.4
In 8/7/76	745	775	805	855	850	835	645	635	1440
8/13/76	725	760	805	810	840	825	620	590	1430
Out 8/18/76	-	730	735	-	-	820	-	-	1355
Out 8/27/76	715	-	-	820	785	810	620	600	-
Change	-30	-45	-70	-35	-65	-25	-25	-35	-85
% Change[1]	-4.0	-5.8	-8.7	-4.1	-7.6	-3.0	-3.9	-5.5	-5.9
In 9/14/76	740	805	865	845	870	900	655	665	1445
9/23/76	725	810	795	845	900	875	645	680	1380
Out 9/27/76	-	-	-	-	880	865	610	640	1340
Out 9/28/76	745	785	675	780	-	-	-	-	-
Change	5	-20	-90	-65	10	-35	-45	-25	-105
% Change[1]	0.7	-2.5	-10.7	-7.7	1.1	-3.9	-6.9	-3.8	-7.3
In 11/9/76	780	785	665	840	920	940	640	680	1380
Out 11/13/76	-	825	730	865	950	950	660	690	1365
Change	-	40	65	25	30	10	20	10	-15
% Change[1]	-	5.1	9.8	3.0	3.3	1.1	3.1	1.5	-1.1

1 Percent change in weight, from first day to the last day, for that grazing period.
2 Cow #6 calved 2/20/77 - 55 lb. bull calf.
3 Cow #248 had a stillborn calf 1/25/77

Table F. 1. - continued

Date In and Out	Cow Number 6[2]		122	134	135	248[3]	295	362	371	Steer
In 12/9/76	795		785	690	835	865	890	660	645	1345
Out 12/14/76	745		725	645	805	865	840	630	615	1235
Change	-50		-60	-45	-30	0	-50	-30	-30	-110
% Change[1]	-6.3		-7.6	-6.5	-3.6	0	-5.6	-4.5	-4.7	-8.2
In 1/14/77	740		735	695	795	-	835	650	-	1330
Out 1/18/77	720		750	655	780	-	795	585	-	1235
Change	-20		15	-40	-15	-	-40	-65	-	-95
% Change[1]	-2.7		2.0	-5.8	-1.9	-	-4.8	-9.9	-	-7.1
In 2/14/77	705		745	-	825	-	805	-	-	1240
Out 2/18/77	725		735	-	795	-	785	-	-	1200
Change	20		-10	-	-30	-	-20	-	-	-40
% Change[1]	2.8		-1.3	-	-3.6	-	-2.5	-	-	-3.2
In 4/12/77	715[2]		890	770	945	800[3]	980	795	790	1440
4/16/77	-		850	720	875	740	935	760	735	1420
4/20/77	-	calf	780	725	890	750	890	695	755	1370
Out 4/24/77	625	140	815	725	860	765	910	690	715	1340
Change	-90		-75	-45	-85	-35	-70	-105	-75	-100
% Change[1]	-12.6		-8.4	-5.8	-9.0	-4.4	-7.1	-13.2	-9.5	-6.9
In 6/17/77	625	200	860	775	945	855	975	785	760	1425
Out 6/25/77	635	190	865	745	905	815	935	765	765	1295
Change	10	-10	5	-30	-40	-40	-40	-20	5	-130
% Change[1]	1.6	-5.0	0.6	-3.9	-4.2	-4.7	-4.1	-2.5	0.7	-9.1

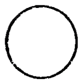
Table F. 1. - continued

Date In and Out	6[2]	calf	122	134	135	248[3]	295	362	371	Steer
	Cow Number									
In 7/12/77	650	200	880	785	925	775	940	780	810	1395
7/17/77	615	205	855	740	890	780	925	745	810	1260
Out 7/27/77	635	205	855	745	890	800	925	760	740	1210
Change	-15	5	-25	-40	-35	25	-15	-20	-70	-185
% Change[1]	-2.3	2.5	-2.8	-5.1	-3.8	3.2	-1.6	-2.6	-8.6	-13.3
In 8/19/77	645	220	875	765	860	775	940	800	740	1250
8/24/77	605	225	840	705	840	725	910	740	700	1235
8/31/77	640	225	885	770	865	800	925	775	805	1200
9/11/77	605	230	875	775	905	775	915	800	765	1265
Out 9/16/77	580	230	835	770	920	800	890	740	715	1195
Change	-65	10	-40	5	60	25	-50	-60	-25	-55
% Change[1]	-10.1	4.5	-4.6	0.7	7.0	3.2	-5.3	-7.5	-3.4	-4.4

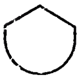
APPENDIX G

CIRCUIT ENERGY SYMBOLS FOR SIMULATION MODEL

Pathway, whose flow is proportional to the quantity in the storage or source upstream.



Outside source, material or energy, a forcing function.



Storage, a compartment within the system, a state variable.

Heat sink, loss of potential energy from further use in the system.

Interaction or work gate, intersection of two pathways coupled to produce an outflow through a mathematical relationship.

Switch, indicates one or more switching actions or choices.

Producer, self limiting energy and/or material receiver, e.g. plants.

Consumer, self maintaining unit, e.g. herbivores.

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BIOGRAPHICAL SKETCH

Burton J. Smith was born in Douglas Wyoming in 1932. After serving in the U.S. Navy he received a bachelors degree in mathematics from San Diego State in 1959. He was a research engineer in the aero-space industry, until he left and pruchased a dairy and diversified farm in Yost, Utah. In 1966 he moved to Eureka Nevada, where he was the owner-operator of a 400 head desert cattle ranch. In 1973 he moved to Lee Kentucky, where he raised corn, soybeans, cattle and hogs.

He entered Western Kentucky in the summer of 1974 and received a MS degree in biology a year later. In January 1976, he enrolled at the University of Florida and began work on his PhD.

He is married to a very understanding woman and has three children.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gerald O. Mott, Chairman
Professor of Agronomy

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John K. Loosli
Visiting Professor of Animal Science

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Darell E. McCloud
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philsosphy.

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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